Thermal Vacuum Testing of a NOAA Weather Satellite

Presented By
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Spacecraft Thermal Vacuum Test - A Point in Time

Monday, August 1, 10:00am – 12:00pm, Room 114

Instructor: Eric Grob, NASA Goddard Space Flight Center

After initially working for the US Navy as a test engineer, Mr. Grob's career in heat transfer began with US Navy radar electronics packaging at RCA, then with satellites at General Electric and Lockheed-Martin where he helped develop the thermal control for several commercial and civil space satellites. Since coming to Goddard Space Flight Center in 1999, Mr. Grob has led the thermal design for several missions, including the Geoscience Laser Altimeter System (GLAS launched 2003) that pioneered the use of propylene loop heat pipes for thermal control in NASA missions. Following this, he was project manager for a solar observing instrument before returning to the GSFC thermal engineering branch as Chief Engineer where he conducts peer reviews and supports mission review panels for numerous GSFC projects, and also provides thermal support for various projects – currently the Geostationary Operational Environmental Satellite (GOES-R) program.

Mr. Grob received his BSME degree from West Virginia University in 1980 and his MSME from Drexel University in 1989.

Spacecraft thermal vacuum testing is the most complicated and longest duration environmental test. This course will look at a specific case – thermal vacuum testing of the first in the latest series of NOAA weather satellites, the Geostationary Operational Environmental Satellite System – that spanned almost two months and was completed late last summer. Based on a heritage satellite bus (the 43rd), and employing watrod to simulate environmental heating, the test design, completion, and post-test analysis is covered in detail, concluding with some remarkable Lessons Learned.

Topics

- Background/Overview
  - Configuration, mission environments, model development (RISTM/DISTM ➔ RISTM/DSTM/SWSTM/PSTM)
- SCTV Development
  - Requirements
  - Configuration (w/major decisions)
    - Detailed target layout (with watrods for later anomaly)
- Pre-Test Analyses
  - Cal Rod Spacing, Setback, and Uniformity
  - Sink Temperature Coupon Test
  - Spectral Shift Analysis
  - Watrod Characterization Test
  - Compare Pre-test Analysis Results to Limits
- Post-Test Analysis
  - Quick-Look Results
  - Correlation (summarize major findings)
- Test Discoveries/Lessons Learned
  - Watrods, add MLI, REAs,
  - SPRU transistor, other transistor: unit repair/retest
- Current status: PSR (w/LAE & RDM liens to ship)

Background/Overview

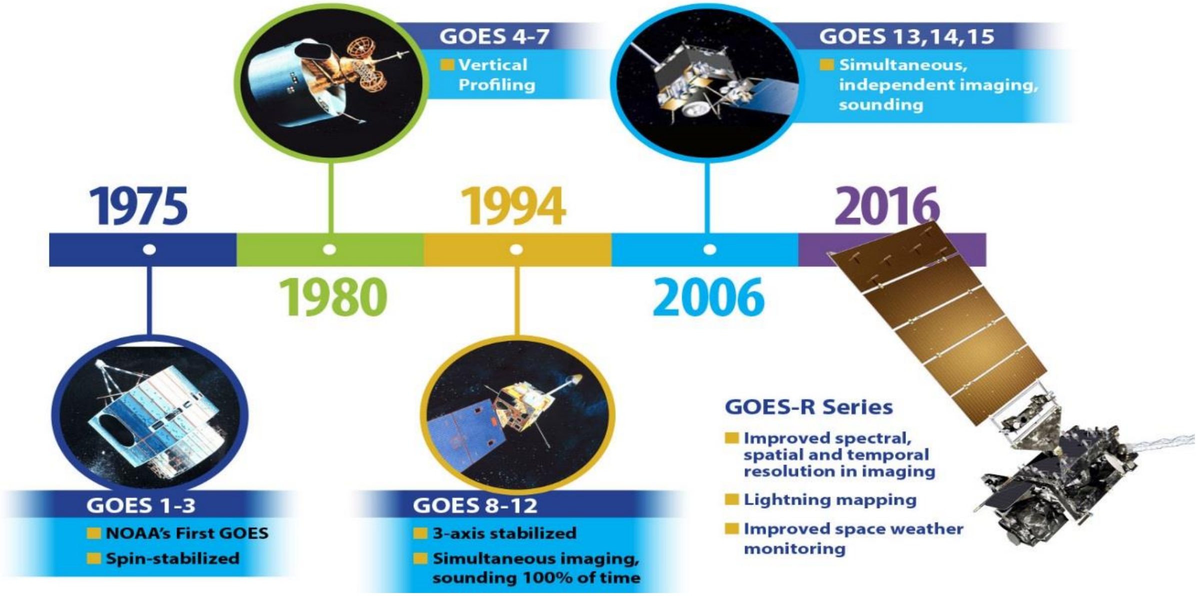
Configuration

Mission environments

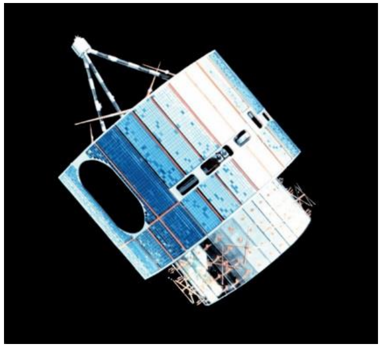
Model development

GOES Background

- The Geostationary Operational Environmental Satellite system (GOES) supports weather forecasting, severe storm tracking, and meteorology research.
- Spacecraft and ground-based elements of the system work together to provide a continuous stream of environmental data.
- The National Weather Service (NWS) uses the GOES system for its United States weather monitoring and forecasting operations, and scientific researchers use the data to better understand land, atmosphere, ocean, and climate interactions.
- The GOES system uses geosynchronous satellites which—since the launch of SMS-1 in 1974—have been a basic element of U.S. weather monitoring and forecasting.

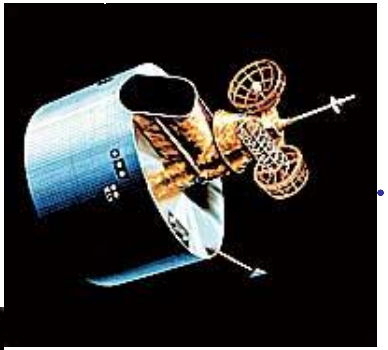


GOES History



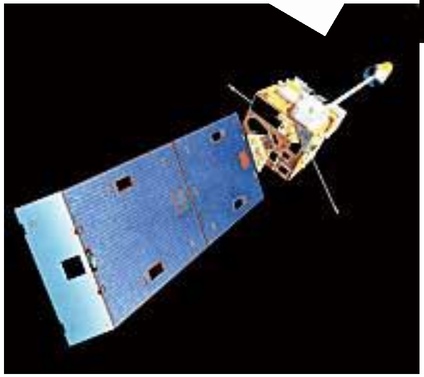
GOES A-C (1-3)

- **Spin-stabilized,** viewing Earth only about ten percent of the time and provided data in only two dimensions.
- Instrument **shared same optics system**, limiting data from each.
- No indication of cloud thickness, moisture content, temperature variation with altitude, or any other information in the vertical dimension.



GOES D-H (4-7)

- **Spin-stabilized**
- Added capability to obtain vertical profiles of temperature and moisture throughout the atmosphere: giving forecasters a more accurate picture of the intensity and extent of storms, allowed them to monitor rapidly changing events, and to predict fog, frost and freeze, dust storms, flash floods, and even the likelihood of tornadoes.
- However, as in the 70s, the imager and sounder still **shared the same optics system,** which meant the instruments had to take turns.



GOES I-M (8-12)

- **Three-axis stabilized** and **separate instrument optics meant instruments could work simultaneously**.
- Real improvement in the resolution, quantity, and continuity of the data. Forecasters had much more accurate data with which to better pinpoint locations of storms and potentially dangerous weather events such as lightning and tornadoes.
- The satellites could temporarily suspend their routine scans of the hemisphere to concentrate on a small area of quickly evolving events to improve short-term weather forecasts.

GOES N-P (13-15)

- **Three-axis stabilized**
- GOES-N, O, and P further improved the imager and sounder resolution with the Image Navigation and Registration subsystem, which uses geographic landmarks and star locations to better pinpoint the coordinates of intense storms.
- Detector optics were improved and because of better batteries and more available power, imaging is continuous.

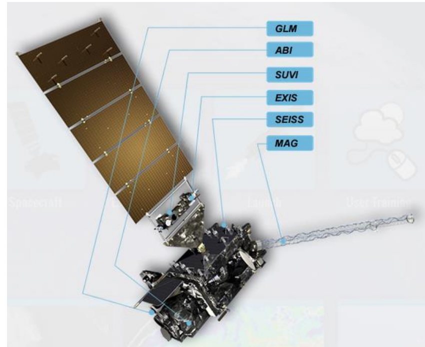
GOES- R Instruments

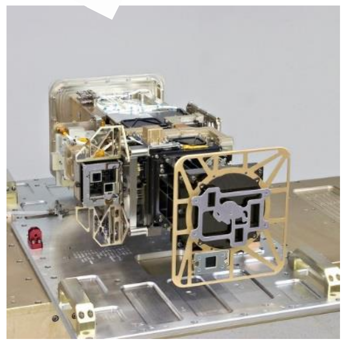
ABI (Advanced Baseline Imager)

- Images Earth's weather, oceans, and environment - improves current products (faster imaging, higher resolution and more accurate calibration) and adds new products for severe weather forecasting:
  - volcanic ash advisories, fire and smoke monitoring, and more.
- 16 different spectral bands vs 5 currently
  - two visible channels, four near-infrared channels, and ten infrared channels.
- Provides 3x spectral information, 4x spatial resolution, and more than 5x faster coverage than the current system.

SEIS (Space Environment In-Situ Suite)

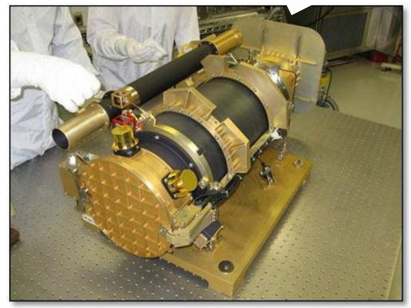
- Monitors proton, electron, and heavy ion fluxes at geosynchronous orbit.
- Data used to assess ESD risk and radiation hazard to astronauts and satellites and warn of high flux events, mitigating damage to radio communication





EXIS (Extreme Ultraviolet and X-ray Irradiance Sensors)

- Monitors solar irradiance in the upper atmosphere.
- Detect solar flares that could interrupt communications and reduce navigational accuracy, affecting satellites, high altitude airlines and power grids on Earth. magnetosphere



SUVI (Solar Ultraviolet Imager)

- Monitors the Sun in the extreme ultraviolet (EUV) wavelength
- observations of solar flares and solar eruptions will provide an early warning of possible impacts to Earth's space environment and enable better forecasting of potentially disruptive events on the ground.

GLM (Geostationary Lightning Mapper

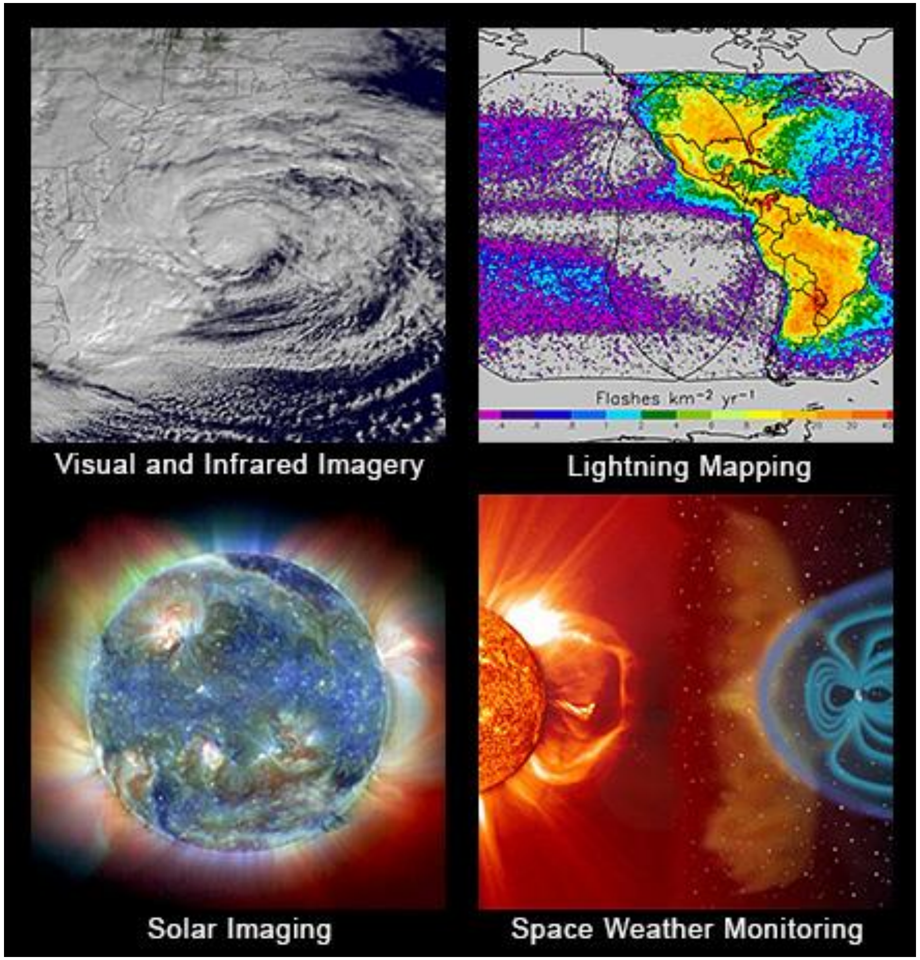
- Detect and map total lightning activity over the Americas and adjacent ocean regions.
- Provide early predictions of intensifying storms and severe weather events.

MAG (Magnetometer)

- Measures the magnetic field in the outer portion of the magnetosphere

Science / Data

- GOES-R is the nation's next generation of geostationary weather satellites. The GOES-R series will significantly improve the detection and observation of environmental phenomena that directly affect public safety, protection of property and our nation's economic health and prosperity.
- The satellites will provide advanced imaging with increased spatial resolution and faster coverage for more accurate forecasts, real-time mapping of lightning activity, and improved monitoring of solar activity.
- The GOES-R series is a four-satellite program (GOES-R/S/T/U) that will extend the availability of the operational GOES satellite system through 2036.
- Collect and transmit up to 100Mbps instrument payload data from each location continuously
- Continuous rebroadcast function at L-Band up to 31 Mbps utilizing dual polarization
- Provide continuing services [Search and Rescue, Data System Collection, Emergency Manager's Weather Information Network (EMWIN)]

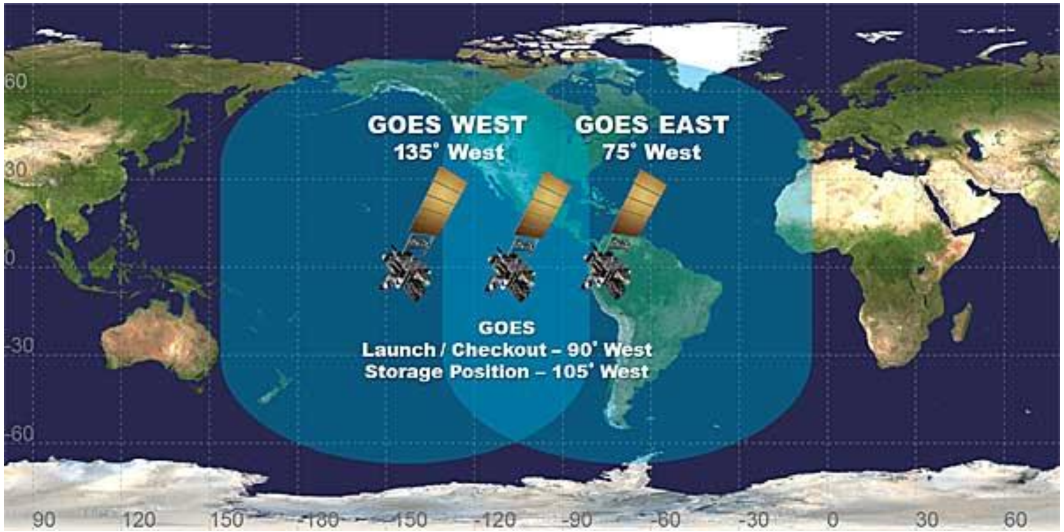


…. So It "GOES"……..

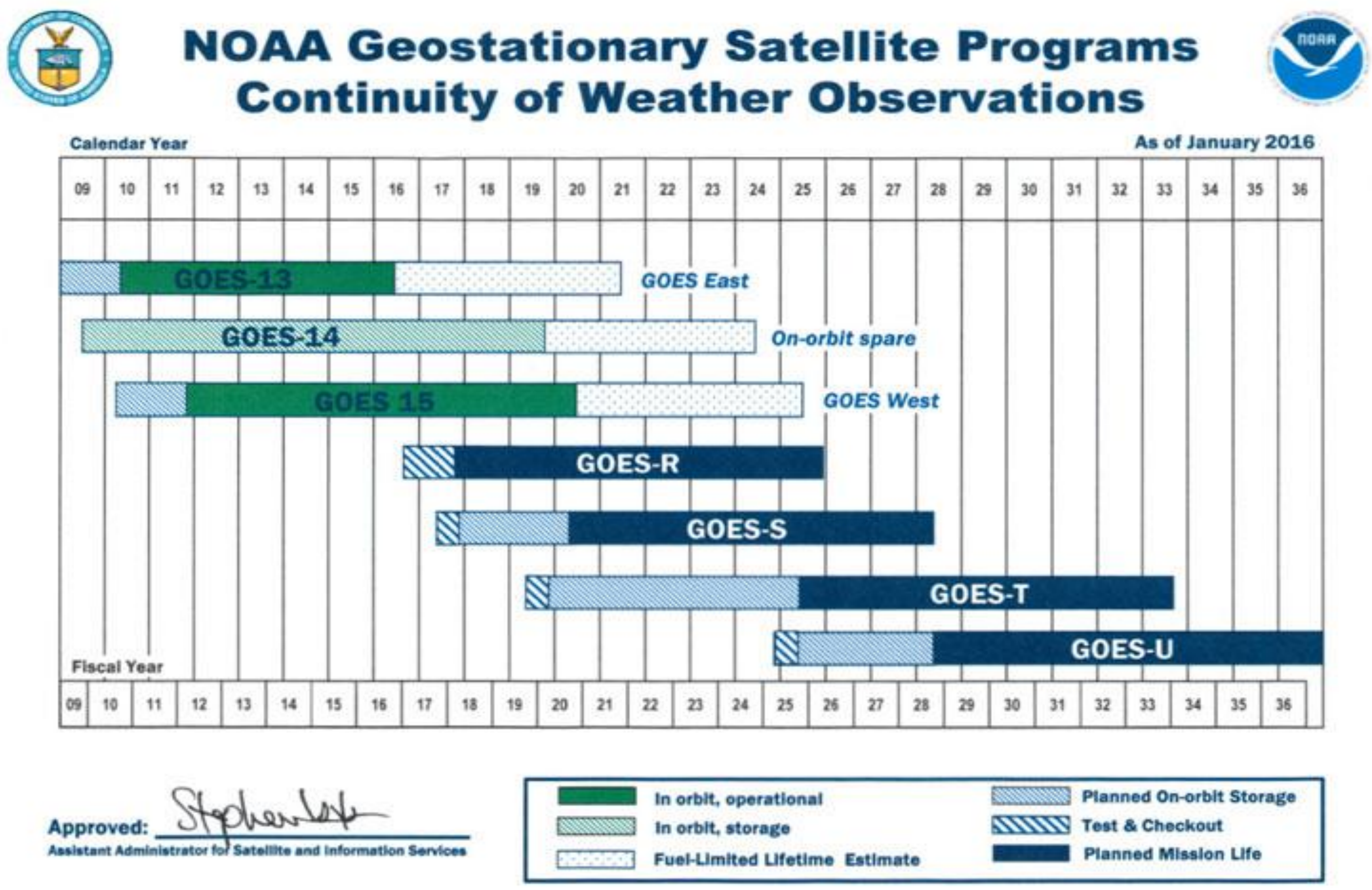
GOES-1 Image

GOES-R Image (sim)

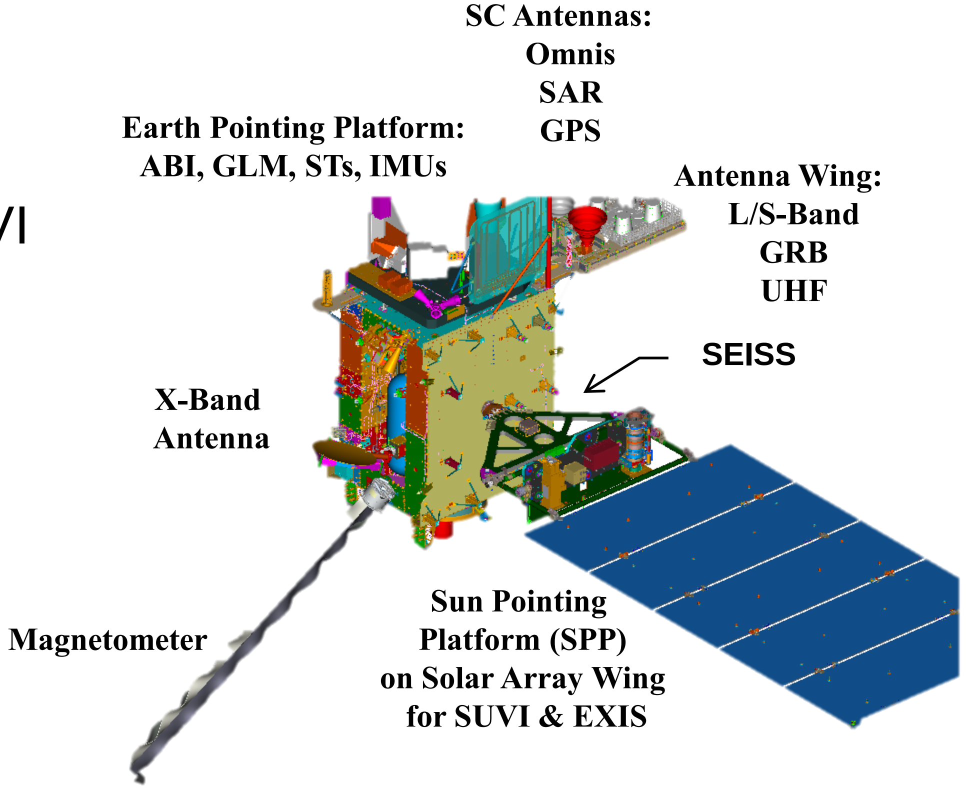
GOES orbit positions.



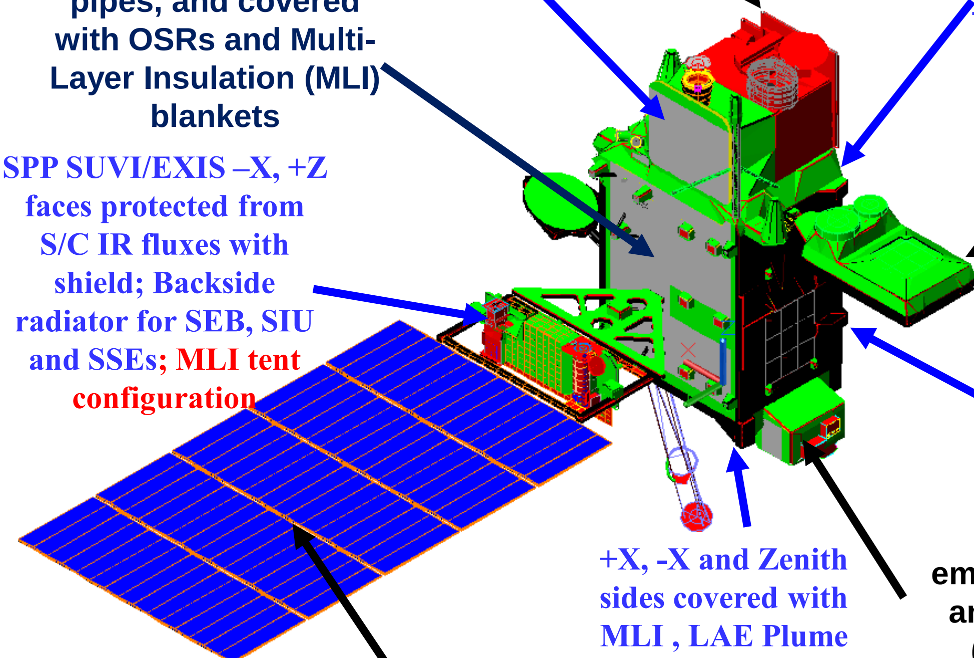
The Aging Fleet



- Based on heritage Lockheed-Martin A2100 bus.
  - 3-axis stabilized, ~5600kg launch mass, Li-I batteries, single solar array (~5kW)
- Science instruments:
  - Earth-pointing: ABI, GLM
  - Sun-pointing: EVE, SUVI
  - In-situ: MAG, SEISS
- 34 meteorological, solar and space weather products.
  - An additional 31 products may be made available as future capabilities for the GOES-R Series



SC Overview - Thermal



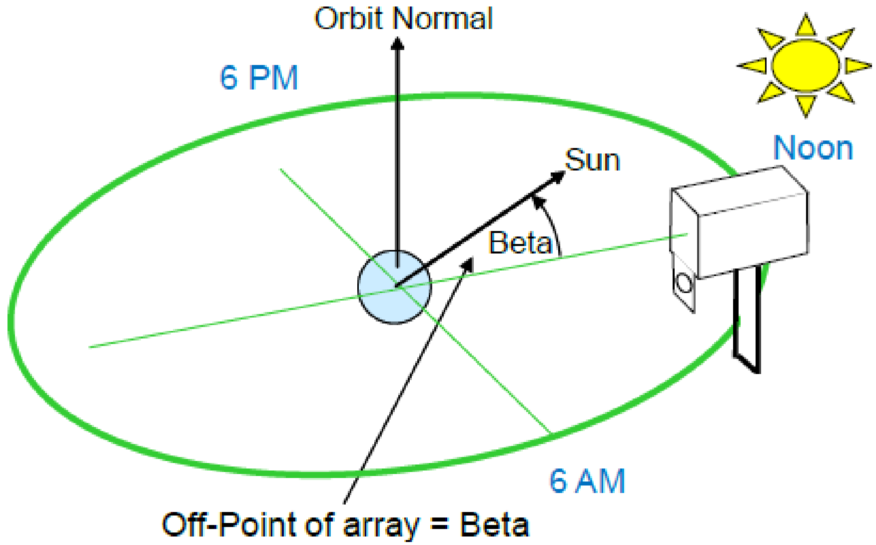
Standard active heater control
- Maintains temperature levels and gradients
- Controlled by FSW
- Commandable set points

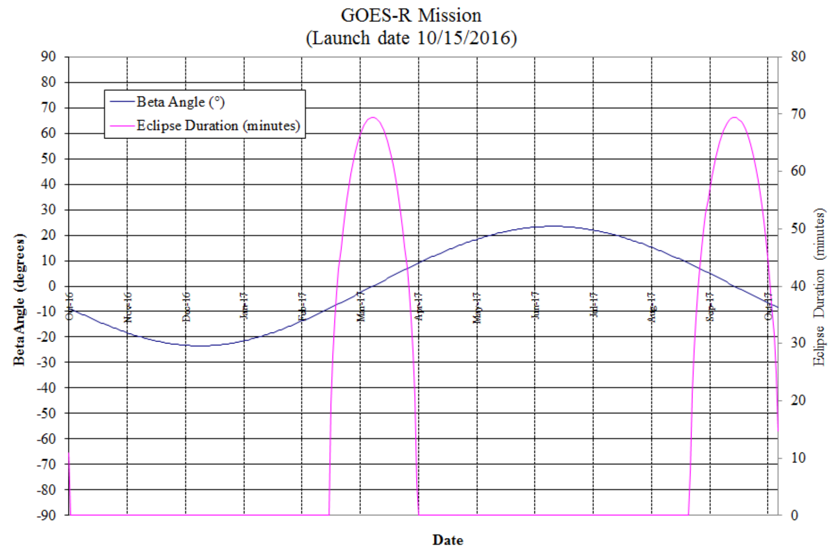
Mechanical thermostats
- On/off control for solar array / antenna wing deployment mechanism damper heaters

Standard heat pipes
- S/C radiators
- GLM radiator
- SEISS assembly
- IMU cold plate radiator

Standard MUVR/IO-coated OSRs
- Reflects solar energy
- Radiates heat
- Meets ESD requirements

- Geosynchronous orbit is well understood
  - +/- 23.5° sun angle varies seasonally, peaking at solstices and is zero at equinoxes
  - Eclipse season twice yearly for ~45 days and peaking at ~70 minutes
  - 1326 < SOL < 1422 W/m2





SCTV Development

Requirements

Configuration

Target/sink layout

SCTV Requirements - General

- All flight hardware shall be subjected to thermal-vacuum (TV) testing in order to demonstrate satisfactory operation in modes representative of mission functions at temperatures in excess of the extremes predicted for the mission
- Every unit shall undergo 12 TV cycles prior to launch, this applies to flight spares as well as to repaired units.
- The last 350 hours of operating/power-on time shall be trouble-free.
  - Trouble-free operation shall include at least 200 hours in thermal-vacuum per side.
- CPT's shall be performed, as a minimum, at the following points:
  - Pre-environmental (baseline)
  - Ambient prior to Thermal Vacuum
  - Hot plateau of first and last cycles of Thermal Vacuum
  - Cold plateau of first and last cycles of Thermal Vacuum
  - Ambient post Thermal Vacuum
- LPT's shall be performed, as a minimum, at the following points:
  - During Thermal Vacuum or Thermal Cycling where dwells are of short duration

SCTV Requirements – TV Cycles

- The first in the series of system level satellite thermal vacuum tests shall be performed to the protoflight temperature levels.
- Four (4) thermal-vacuum cycles shall be performed at the spacecraft/instrument system level of assembly.
  - The 4 cycles shall be comprised of 3 short duration cycles followed by an extended hot and cold cycle.
  - The duration of each of the first 3 hot TV plateaus shall be at least 4 hours long.
  - The duration of each of the first 3 cold TV plateaus shall be at least 24 hours long.
  - The duration of the 4th hot and cold TV plateaus shall be subject to the required system test time.
- All required performance testing shall be completed by the end of the 4th hot and cold TV plateaus. (See CPT/LPT requirement)
- All spacecraft bus redundant components/units as well as all internally redundant single components/units shall demonstrate compliant performance at both hot and cold temperatures.
- All instrument redundant components and any internally redundant instrument sides shall be exercised during both hot and cold performance tests.
- Cold start and hot restart shall be demonstrated during the system level test.

SCTV Requirements – Thermal Balance

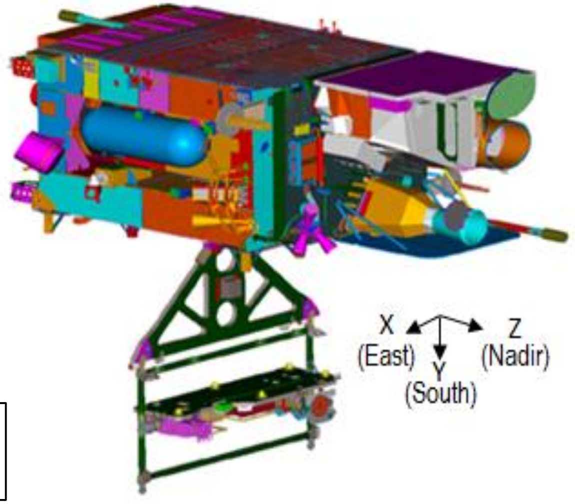
- TB test shall demonstrate the thermal control system performance by operating in (simulated) worst hot and cold case thermal environment.
- Guard heaters shall be used to minimize uncontrolled heat leaks thru test harnesses and any other non flight component that could affect the thermal balance results.
- The system level Thermal Balance tests for each spacecraft shall at least include Winter Solstice, Summer Solstice and Equinox with Eclipse.
- Thermal Balance stability shall be considered achieved when spacecraft temperatures change less than 0.5ºC per hour for at least 3 hours with a decreasing slope over that 3 hour period and the temperatures are within 2° C of the final projected steady state temperature.
- The correlated analytical model shall be accurate to within 5° C for all "relevant" spacecraft bus hardware and 3° C for all "relevant" instrument hardware
- TV testing shall demonstrate the ability of survival heaters to maintain units within Non-Operating temperature limits during worst cold environments, minimum voltage and while the units are off.
- Testing shall demonstrate that operational and survival heaters maintain applicable components within their operating and non-operating MATs respectively.
- Both operational and survival heater set points and heater control (including primary and redundant circuits) shall be independently verified.

SCTV Design Objectives

- Goal
  - Get Satellite to proto-flight temperatures
  - Perform required thermal balance conditions to verify thermal design and data for model correlation.
  - Environment must be adjustable to properly simulate the required seasonal conditions (WSEOL, SSEOL, AEBOL)
- Design Considerations
  - Different portions of satellite have different proto-flight requirements, e.g., batteries, ABI, GLM, SEISS, equipment panels, etc.
  - Basic orientation driven by standard fixture, in either horizontal or vertical orientation.
    - Vertical: Large heavy ABI targets lowered into chamber and located over SC; 30-50% of the heat pipes would be in reflux
    - Horizontal: tight chamber fit; maintain levelness of heat pipes
- Original concept was to use "warm wall" approach per commercial satellite practice
  - Cold soak at -150° C to -170° C, then warm to 45° C for cycles, but this wouldn't allow "zoning" without excessive coldplates/MGSE.
  - Contamination concerns

SCTV Implementation

- Chamber walls will be at cryogenic temperatures the entire test
  - GSE heating sources to provide combination of simulated mission environmental heating
  - Identify zones that require independent temperature control
  - Isolate each zones (via baffles) such that the environment may be varied independent of other zones
- Horizontal configuration to utilize standard fixture
  - Large quantity of heat pipes (>100) in PY nd MY radiators will be horizontal, leaving only a few in reflux (3 in SEISS cabinet and 2 on IMU Coldplate).
- SC Configuration
  - “Deployed” solar array (no panels)
  - “Stowed” Magnetometer
  - No Antenna Wing Assembly (AWA)
  - “Empty” Propulsion tanks



How to Simulate Environmental Heating ?

SCTV – Simulating Environments

- Project requirements for SCTV thermal balance testing includes WSEOL, SSEOL, AEBOL environments.
- Mission thermal analysis was used to determine the “orbit average” sink temperature, for the 3 exterior surface materials on the 6 primary sides of SC:
  - Black Kapton (SC MLI): PX, MX, PZ
  - Stamet (Earth Deck MLI): PZ
  - OSR (Radiators): PY, MY
- Initially, Q_{ABS} data used to calculate T_{SINK}, but this evolved into direct prediction by using small passive “patches” of the correct material, around the 6 sides of the SC.

Table 1. GOES-R SCTV Sink Summary

Zone	Setpoint (°C)					
	COLD	TOSP	WSEOL	SSEOL	AEBOL	HOT
PX (east)	-175	-100	45	-120	-175	40
MX (west)	-175	-100	-175	45	-175	40
PY (south)	-175	-175	-30	-110	-110	30
MY (north)	-175	-175	-175	-60	-175	-30
PZ (nadir)	-175	-175	45	-175	-175	40
MZ (zenith)	-110	-100	-100	45	-110	20

WSEOL	Winter Solstice, EOL
SSEOL	Summer Solstice, EOL
AEBOL	Autumnal Equinox, BOL
TOSP	Transfer Orbit Set Point (heater check)

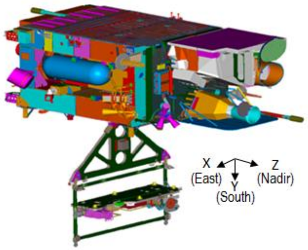
How to Simulate The Environments

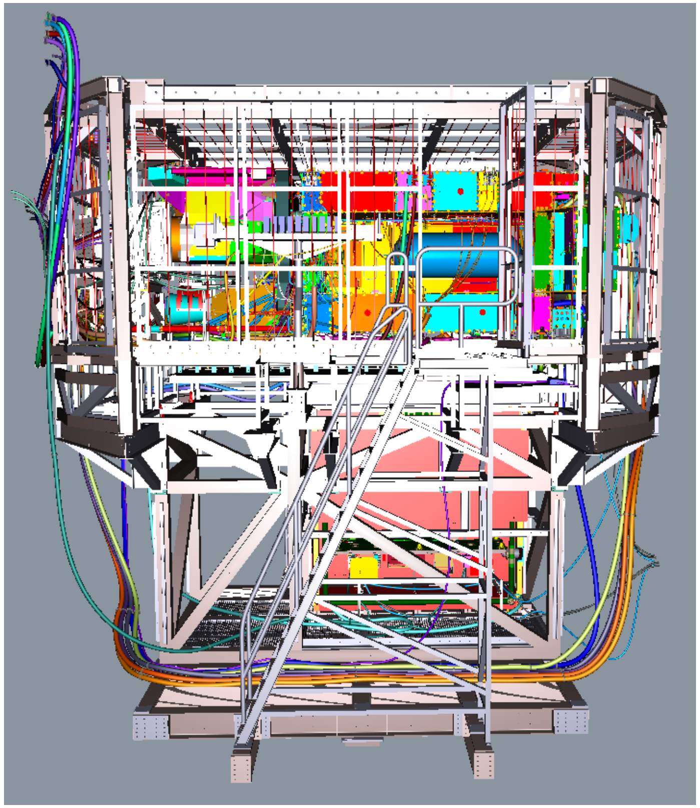
- Various methods exist to simulate range of environments (sinks), with pros and cons for each.
  - Solar sim: not an option
  - Heater plates: good for warm sinks, but more difficult for cold, and longer transition times.
  - Cold plates: costly and heavy MGSE,
  - IR lamps: spectral shift, reliability, large arrays block view to cold shrouds
  - Watrods: spectral shift, smaller size gives good view to cold shroud
- The two large (~6m^2) radiators face up and down:
  - PY looks at fixture and “uncontrolled” mess on the floor
  - MY “sink” to be lowered in after SC, risk for heavy and/or large sink GSE.
  - Other sides are more typical with lateral views to cold shroud (??)

Watrods To Be Used

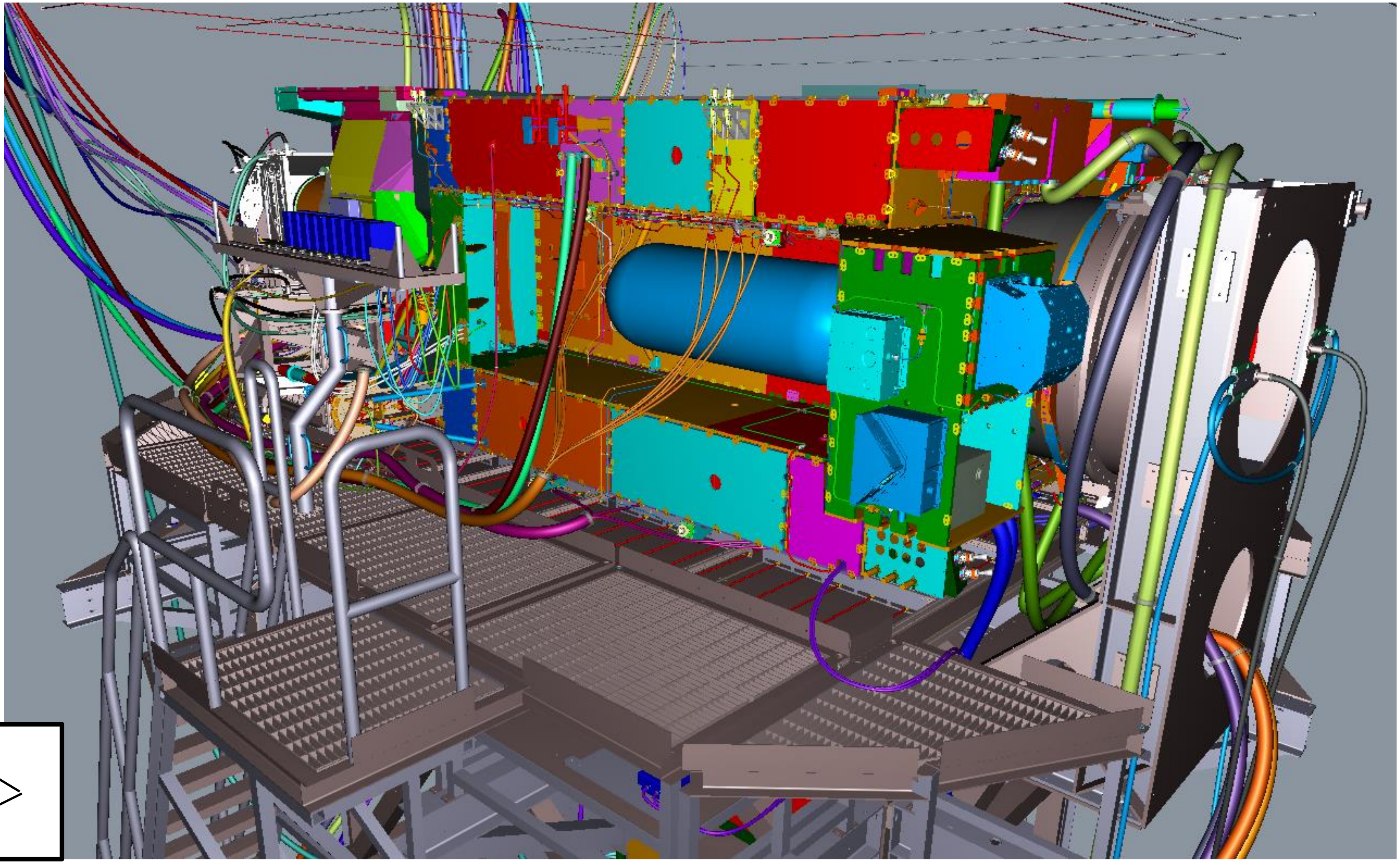
Fitting Watrods in the Chamber

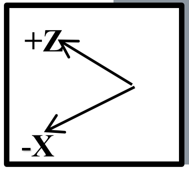
- Watrods were selected to simulate environmental heating, augmented by heater plates, coldplates.
  - Maximize hot to cold environment capability
  - Maintains test article view to cold shroud (or coldplate, if needed)
- Determine maximum temperatures needed to achieve hot balance and plateau sinks, with margin.
  - Ensure sufficient margin to contamination limit of 600° C.
- Concept is to surround the SC with a watrod "cage" and use coldplates where view to shroud is limited. Heater plates used where necessary.



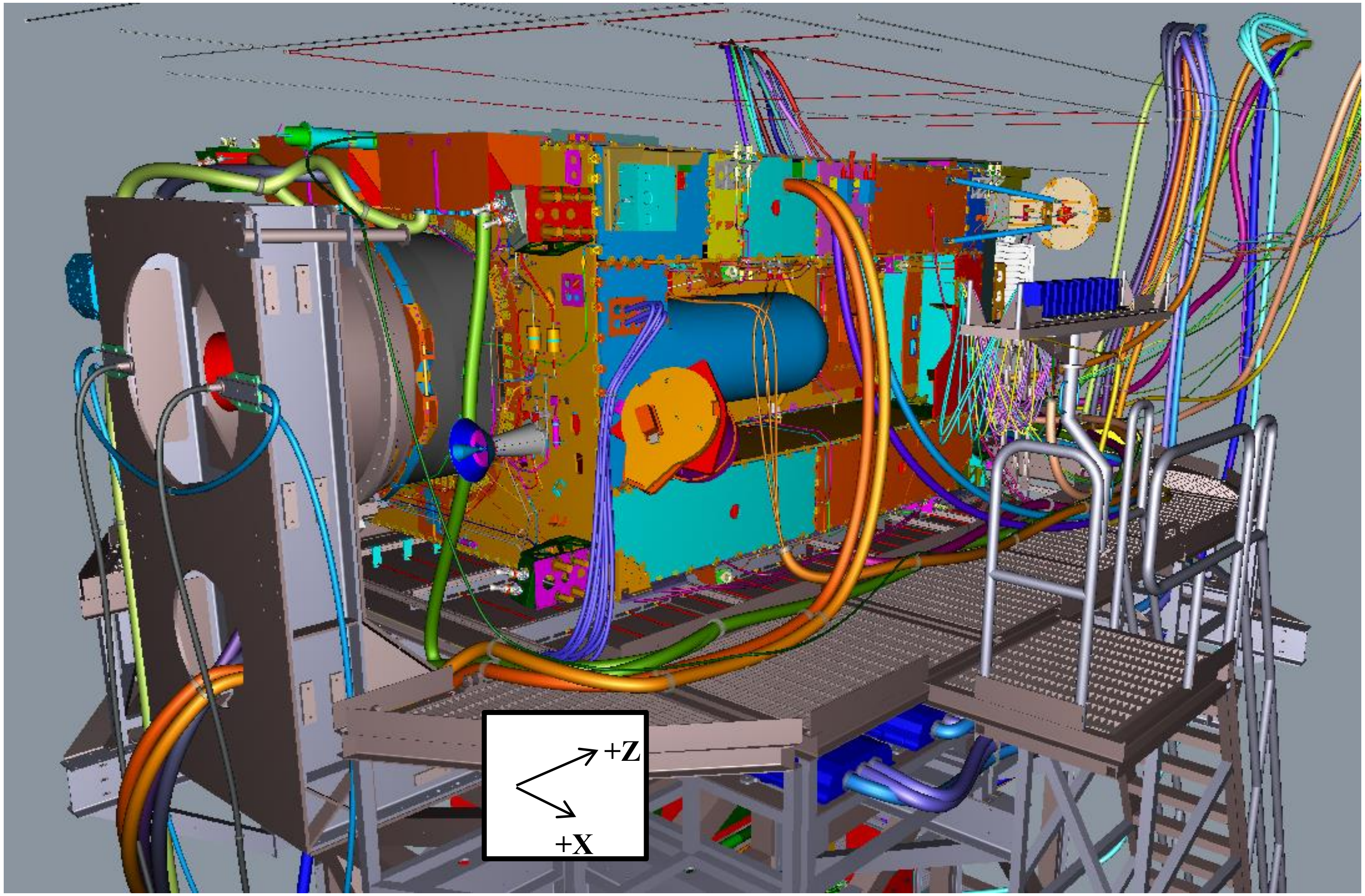


-X View from Aft Corner

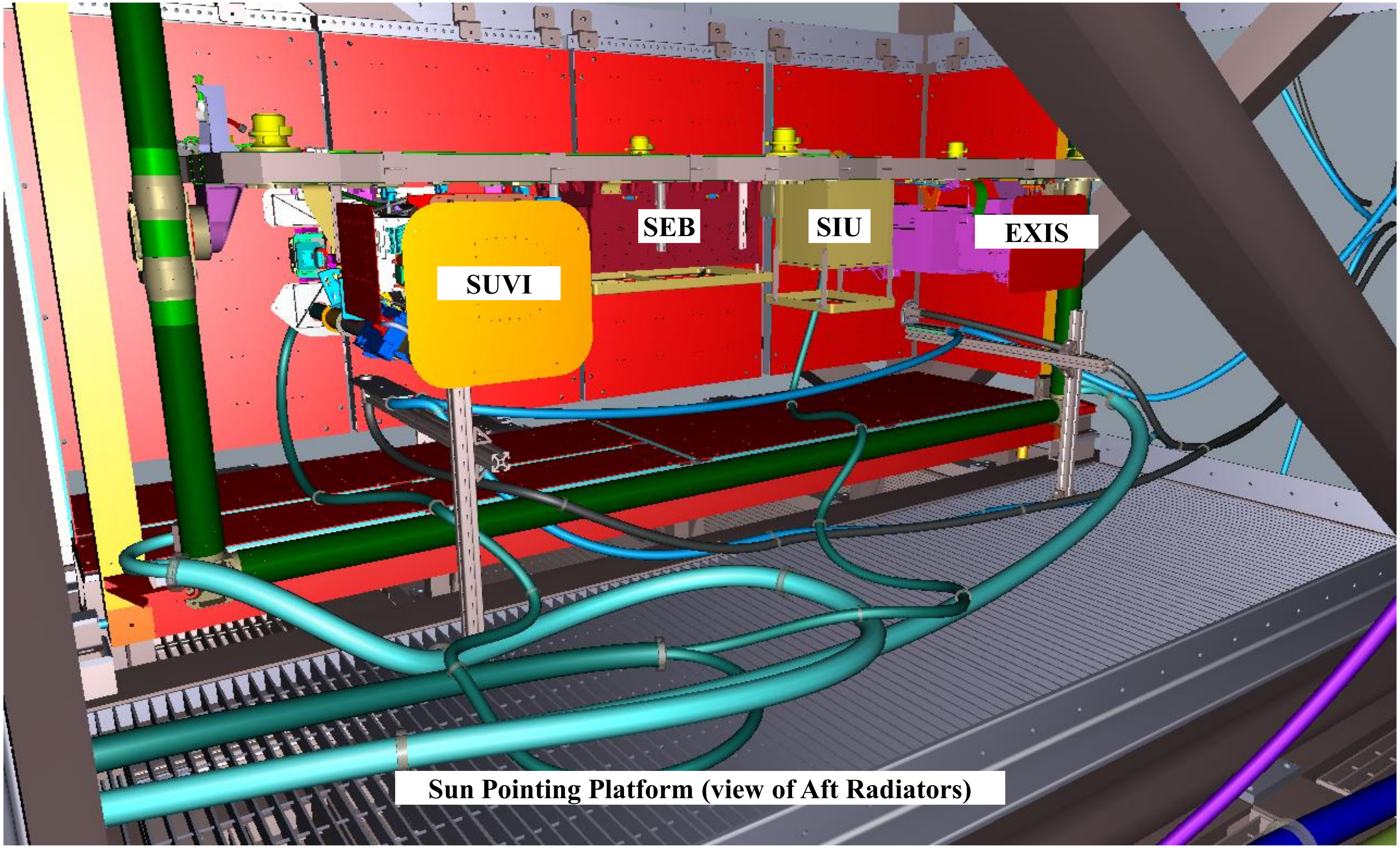




+X View from Aft Corner



SPP Zone (Under SC)



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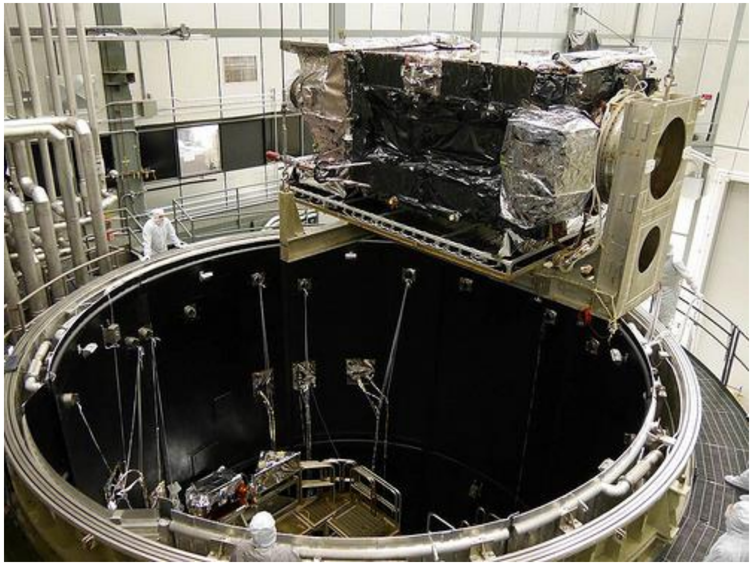
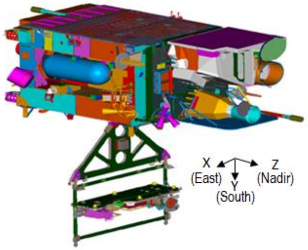
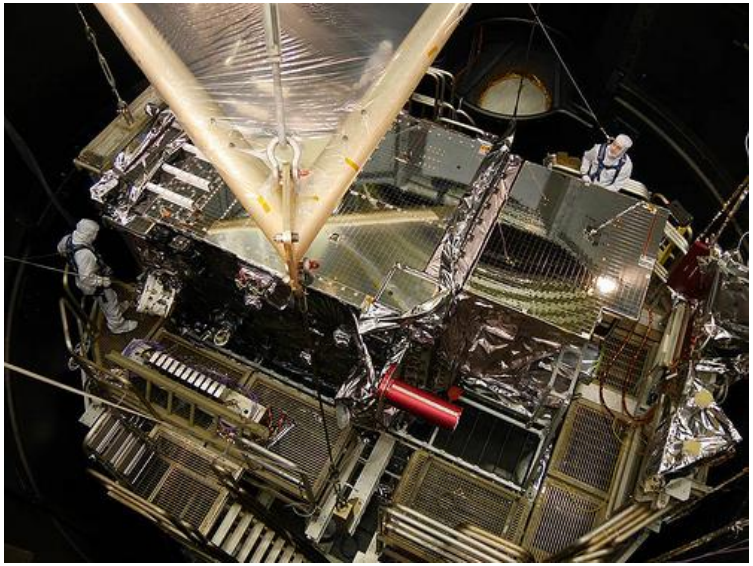
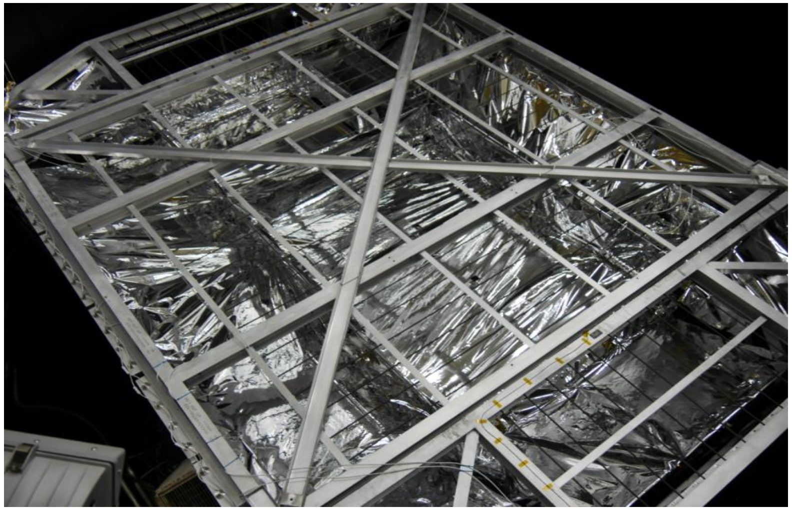
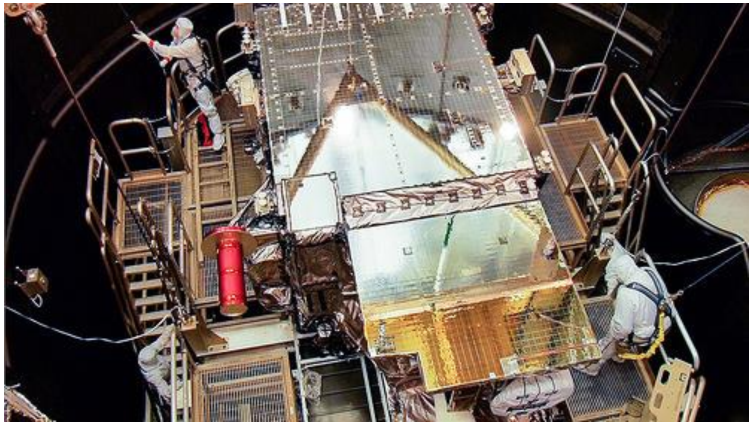
Going Into the Chamber











Pre-SCTV Analysis

Cal Rod Spacing, Setback, and Uniformity

Sink Temperature Coupon Test

Spectral Shift Analysis

Watrod Characterization Test

Compare Pre-test Analysis Results to Limits

Designing the Watrod System

- Watrods provide the simulated environmental flux based on their temperature

  $Q_{ROD} = \sigma \, \varepsilon_{ROD} \, T_{ROD}{}^4$

- Heating from the watrod that is incident upon the Test Article is inversely proportional to distance from watrod: $Q_{SURF} = Q_{ROD} *(r/L)$
  - Closer *spacing* results in a more uniform flux and lower watrod temperature, but also more blockage of view to cold shroud.
  - Closer *setback* results in less uniform flux, and lower watrod temperature.
- Optimizing setback and spacing is key to test design.
  - Based on past experience, 8” spacing and 12” setback selected.

LL 2

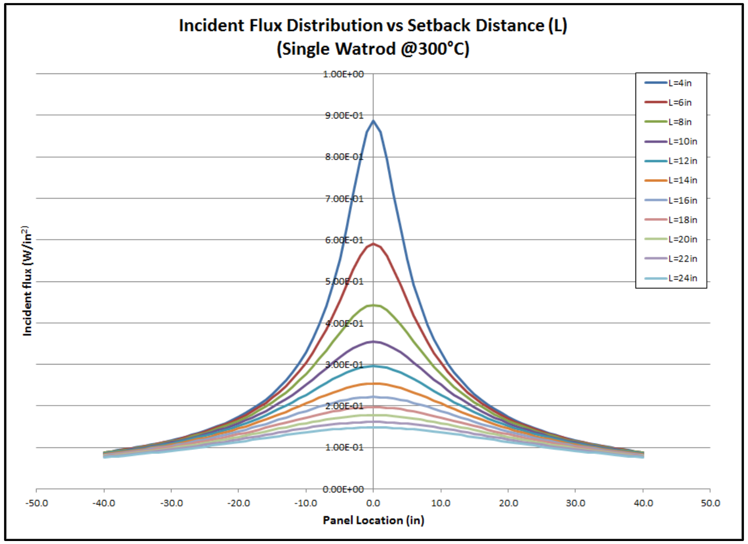
Watrod Setback & Spacing

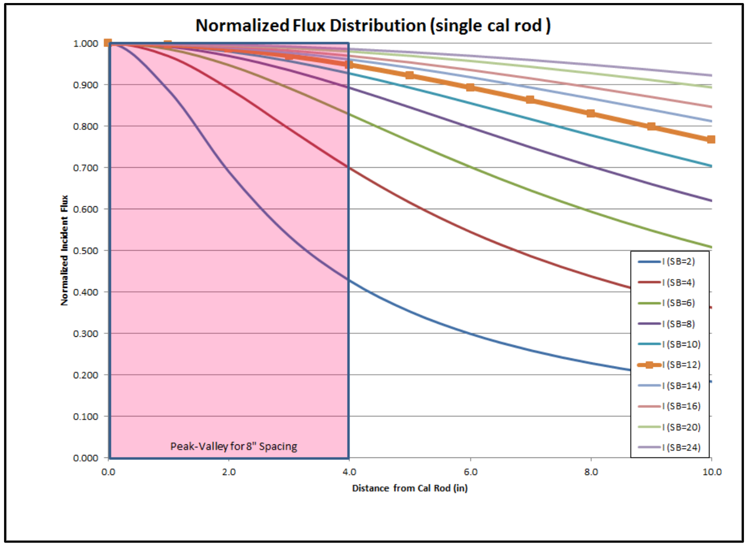
- Watrods provide the simulated environmental flux based on their temperature

$$Q_{ROD} = \sigma\, \varepsilon_{ROD}\, T_{ROD}^{4}$$

- Heating from the watrod that is incident upon the Test Article is inversely proportional to distance from watrod: $Q_{SURF} = Q_{ROD} *(r/L)$
  - Closer *spacing* results in a more uniform flux, but also more blockage of view to cold shroud.
  - Closer *setback* results in less uniform flux, and lower watrod temperature.
- Optimizing setback and spacing is key to test design.

8” spacing and 12” setback selected

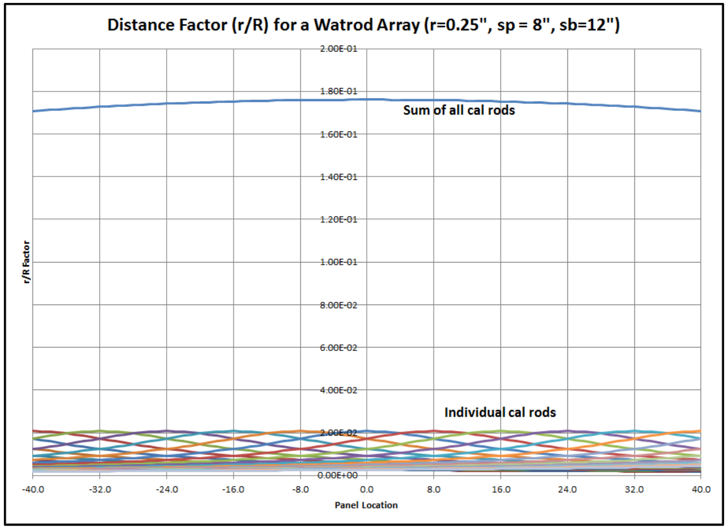


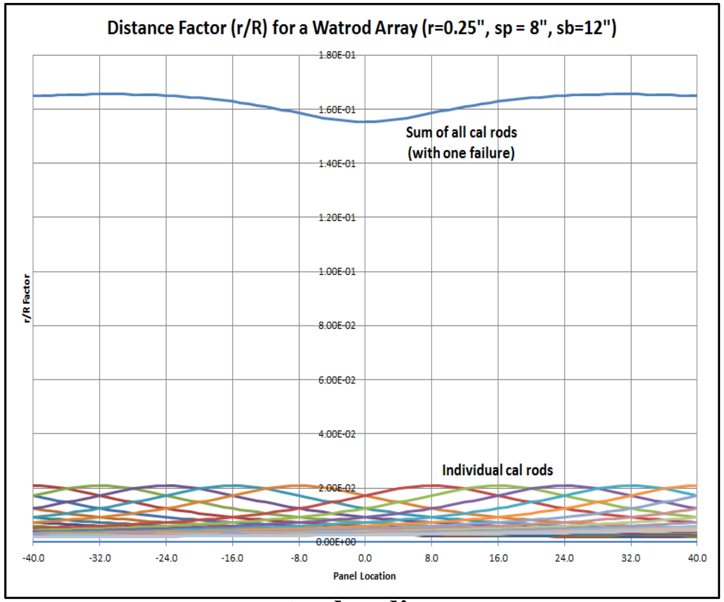


r= watrod radius
L= distance to surface

Watrod Array – Flux Variation

- Nominal 8” spacing and 12” setback results in “smooth” distribution over large radiator surface.
  - ~3% variation
  - ~5% blockage
  - Estimated watrod temperatures for hot case fluxes:
    - OSRs:~275° C
    - MLI: ~450° C
- Specify 600° C as maximum watrod temperature to allow margin for hot protoflight sinks; pre-test bakeout.





r= watrod radius

L= distance to surface

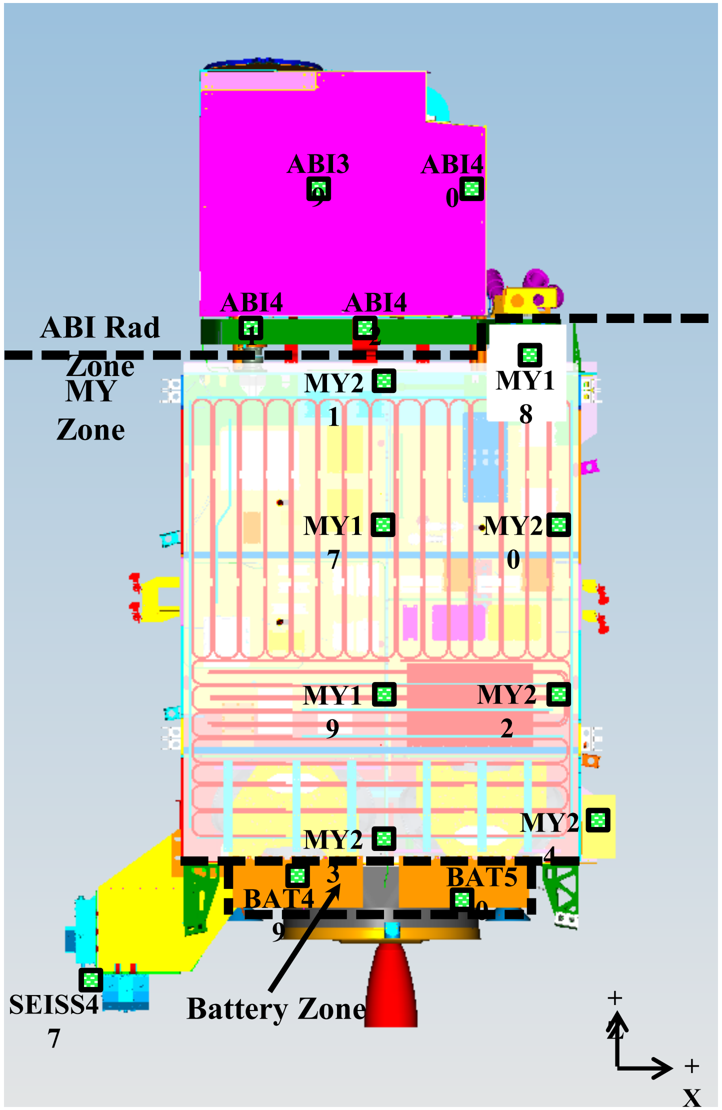
Measuring Sink Temperatures

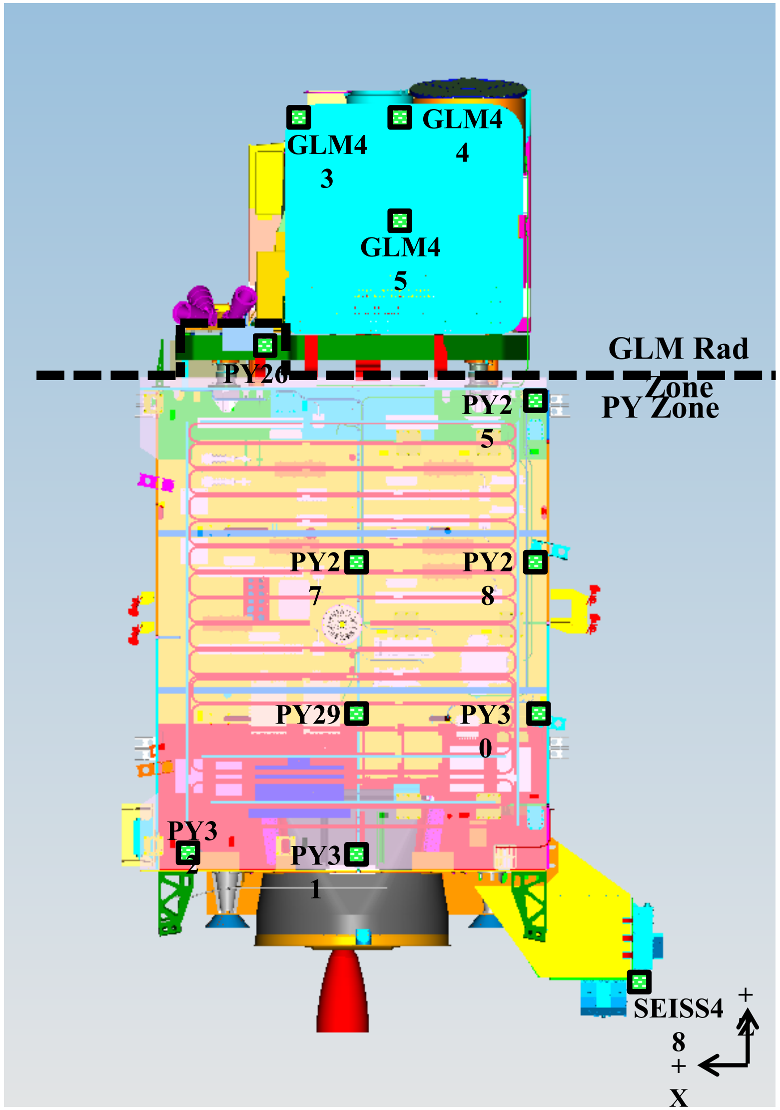
- Definiton: Equivalent sink temperature - the equilibrium temperature that is reached by a “passive surface”.
- Measured during test using small, measurement “coupons”:
  - Heritage design was black kapton material and a TC, mounted to MLI patch (“insulated” from parasitic heating) to provide direct measurement of sink temperature.
  - Model in Thermal Desktop to analytically determine sink temperatures.
- GOES-R thermal materials include OSR (radiator), BK and Sta (MLI).

ESD (Equivalent Sink Detector
AC (Adiabatic Coupon)
..are used interchangeably

OSR = Optical Solar Reflector
Sta = Stamet
BK = Black Kapton

ESD Placement for S/C MY/PY

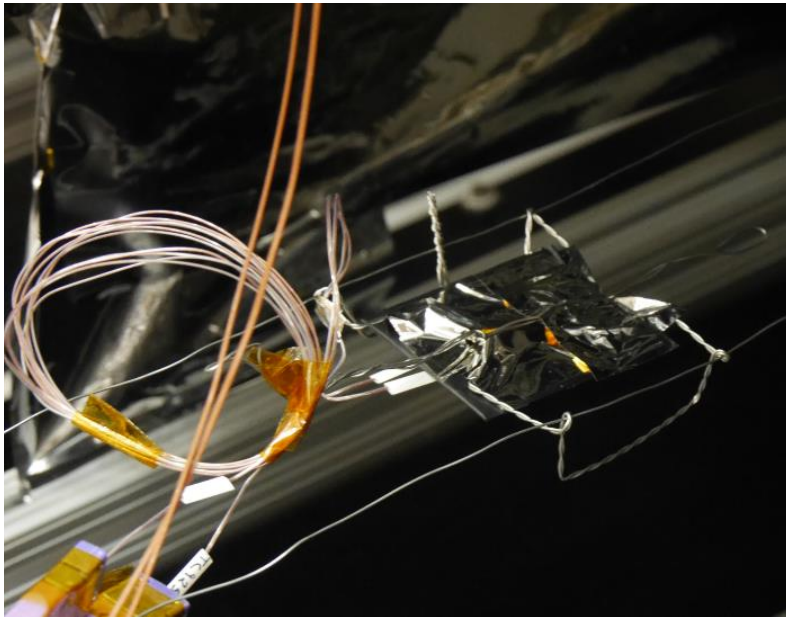


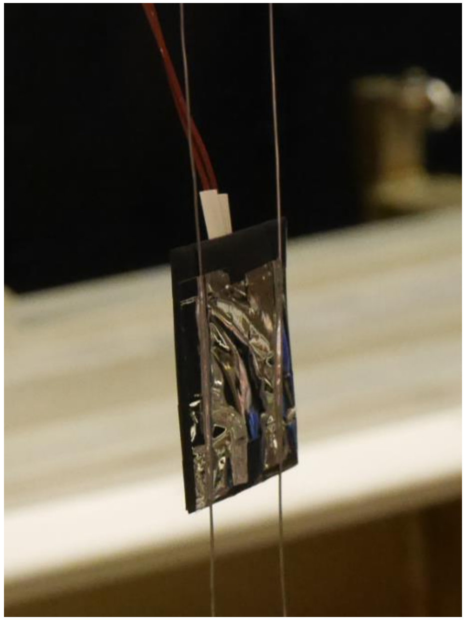


Note: Only zone separation lines in X-Z plane shown

Equivalent Sink Detectors

- Equivalent Sink Detectors (ESDs) or Adiabatic Coupons (AC) used to measure equivalent sinks during SC TVAC for environmental control
  - Based on heritage design
  - Include OSR, Black Kapton and Stamet ESDs



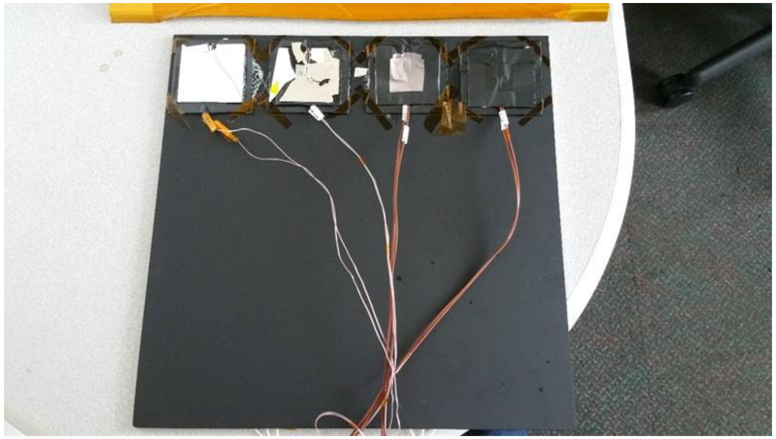


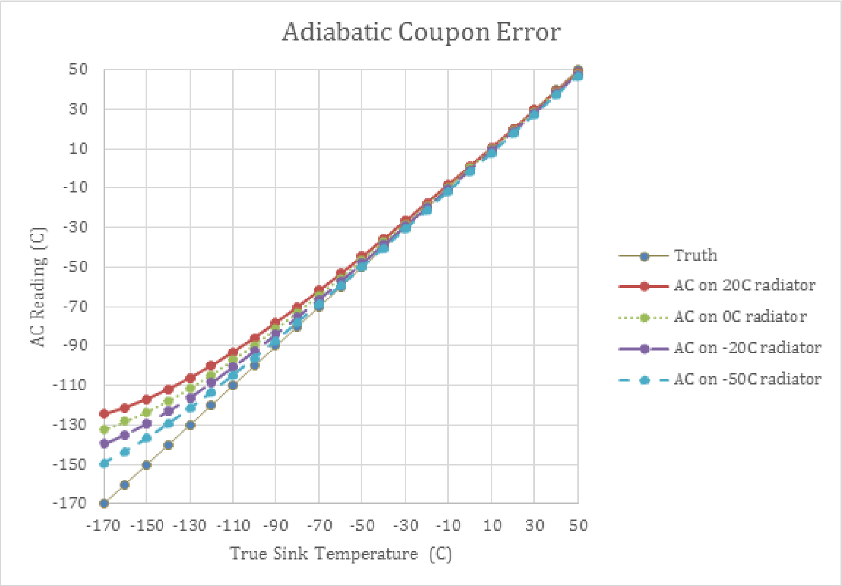
Maintain Alignment

Coupon Testing

LL 3

- Although heritage device, but no engineering test data available.
- GSFC performed engineering test of OSR and Stamet coupons, using various combinations of sink temperatures and "SC" temperatures,
  - Coupons on a controlled heater plate to simulate the SC surface,
  - Temperature controllable coldplate sink
- Simulated different SC temperatures over a range of sink temperatures.





Results show increasing warm bias (error) at the colder sink temperatures, that gets worse with warmer SC temperatures.

Thermo-optical Properties

- Satellite local environmental heating can include direct and reflected UV and IR, plus IR backloading from SC surfaces.
- Thermal properties (α and ε) of various thermal coatings/materials are calculated from reflectance measurements in two distinct ranges:
  - 250-2500nm: >99% of solar spectral energy (α)
  - 2500-5000nm: reflectance values not typically measured
  - 5000-25000nm: >96% of IR spectral energy (ε)
- Emittance (ε) is typically calculated from reflectance measurements integrated with IR spectral distribution of a 300° K emitter:

$$\varepsilon = 1 - \frac{\int_{5000}^{25000} I(\lambda)\ \rho(\lambda) d\lambda}{\int_{5000}^{25000} I(\lambda) d\lambda}$$

Needs to be modified to account for the "gap region":

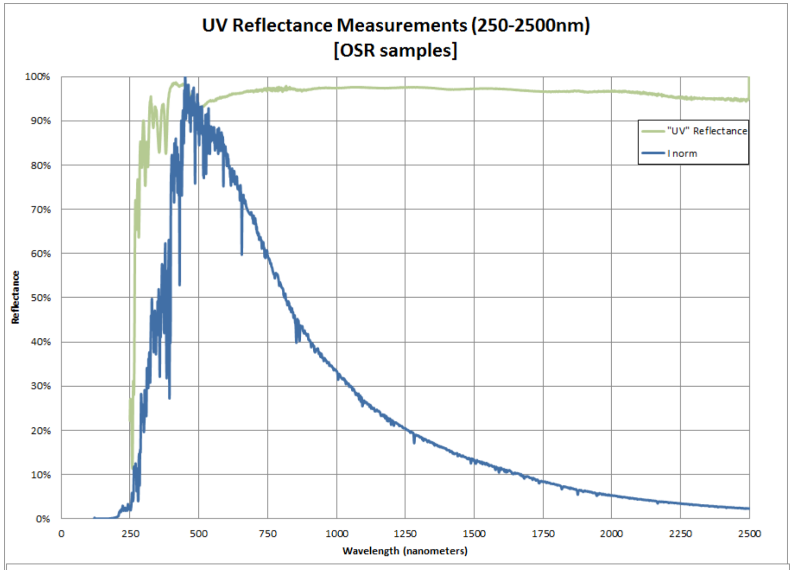
$$\varepsilon = 1 - \frac{\int_{2500}^{25000} I(\lambda)\ \rho(\lambda) d\lambda}{\int_{2500}^{25000} I(\lambda) d\lambda}$$

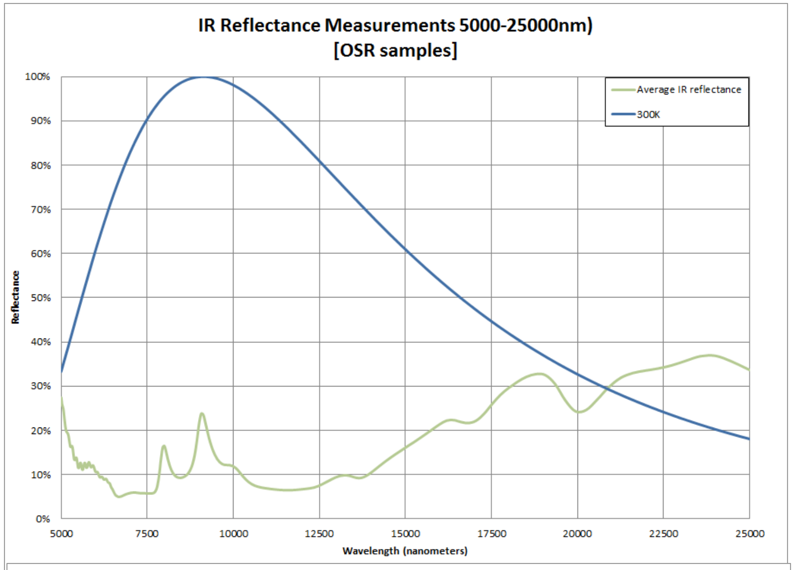
Thermo-optical Properties

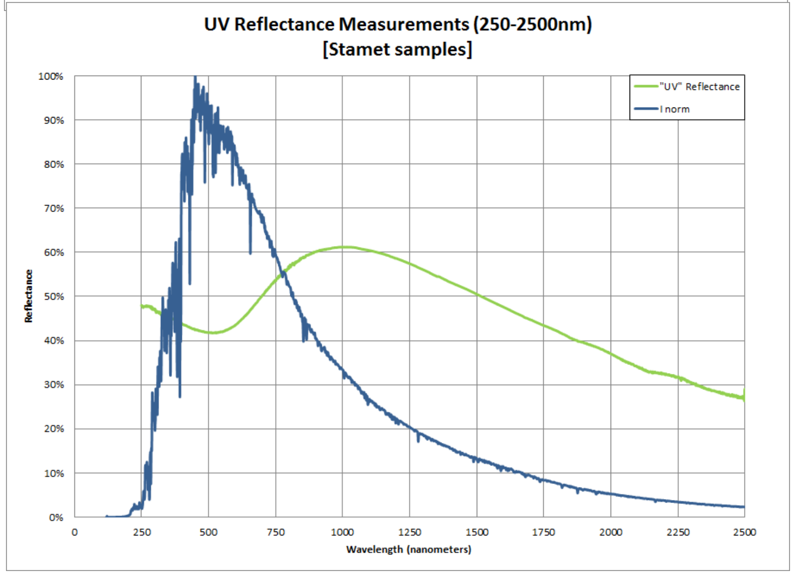
- Planck's Law says that the IR spectral content "shifts" toward the shorter wavelengths as emitter temperature increases, i.e. $I(\lambda)$<5000nm increases significantly with temperature.
- Decision was made to use "matching" material on coupons for each zone, thus alleviating emittance adjustments for different coupon material than the thermal control material in that zone.
- Still, without having reflectance data in the 2500-5000nm range, concern was whether a test unique emittance (ε) for correlation would needed for hot sinks (and watrods).

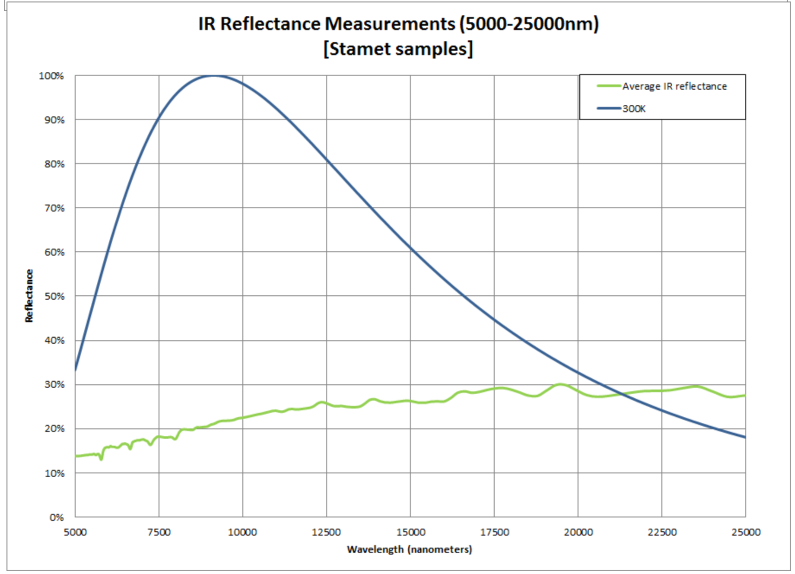
OSR:	**$\rho(\lambda)$<5000nm is higher , less energy is absorbed; emittance should be lower.**
Stamet:	**$\rho(\lambda)$<5000nm is lower , more energy is absorbed; emittance should be higher**
BK:	**$\rho(\lambda)$<5000nm ~ same, so same energy is absorbed; no emittance change..**

Incomplete Spectral Reflectance

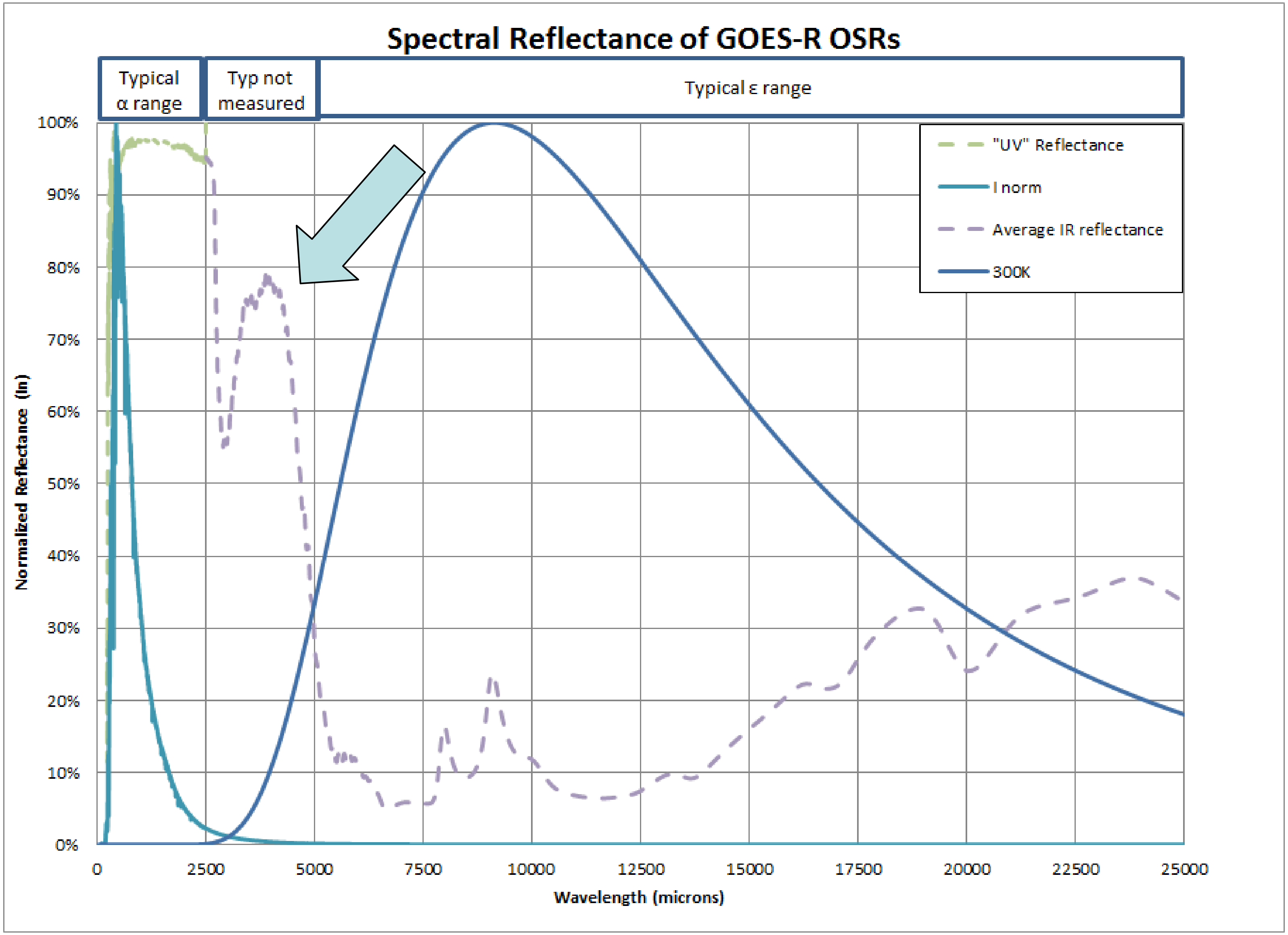




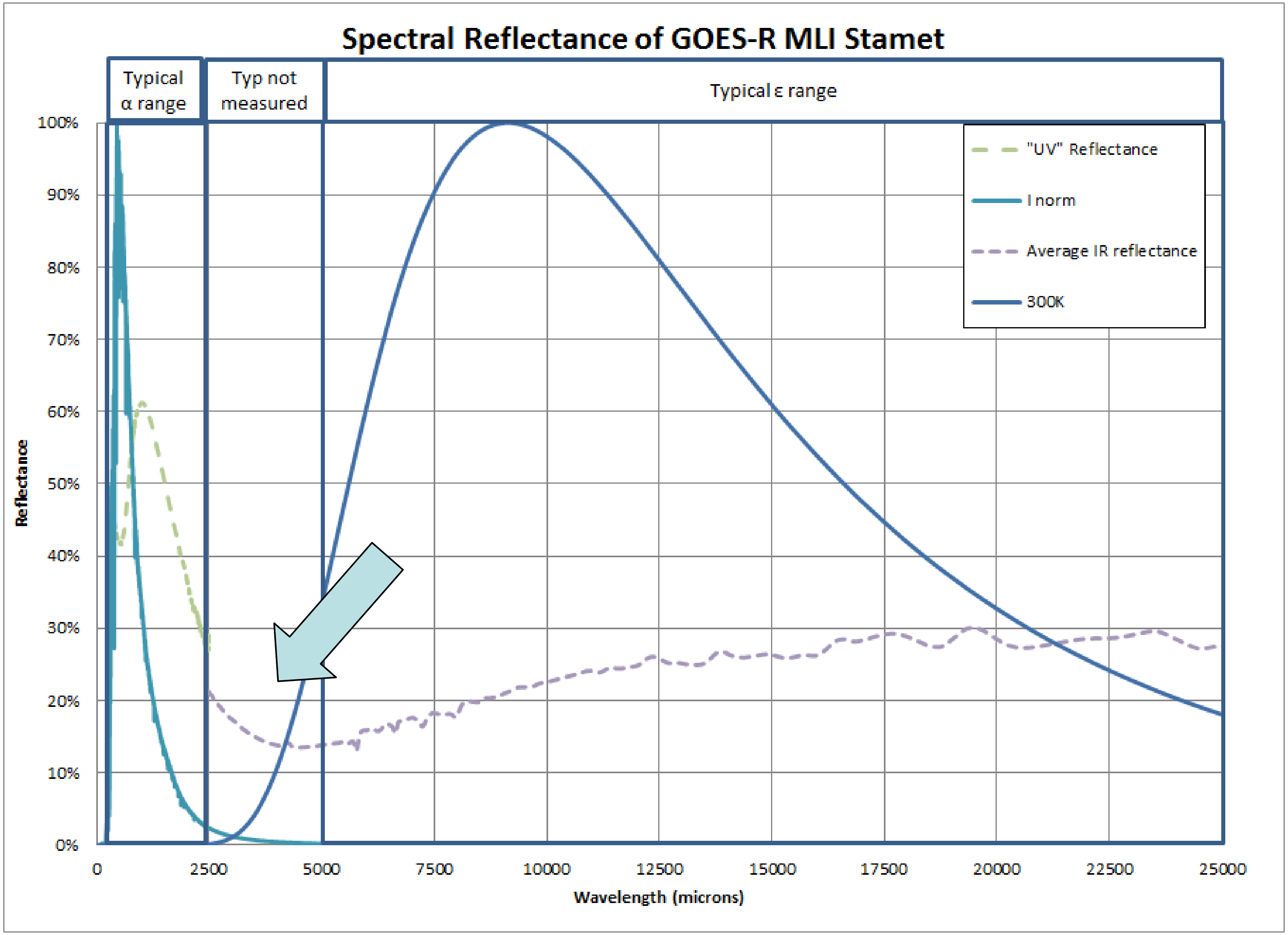




Complete Range (250nm-25,000nm)



Complete Range (250nm-25,000nm)

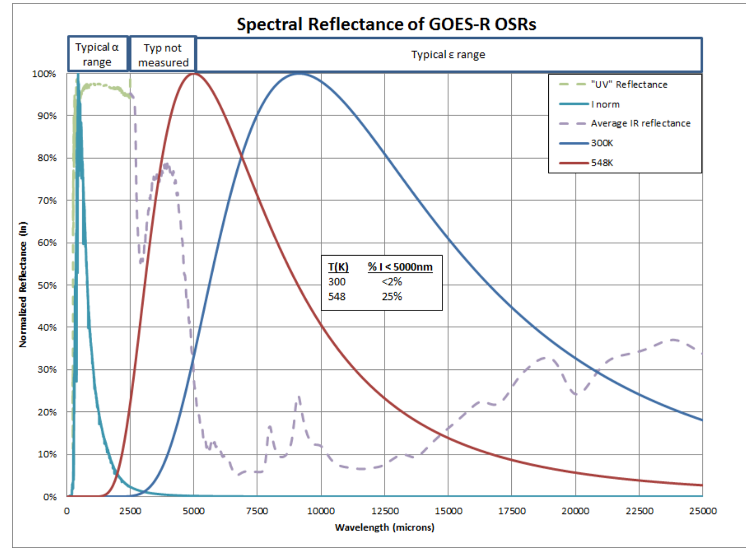


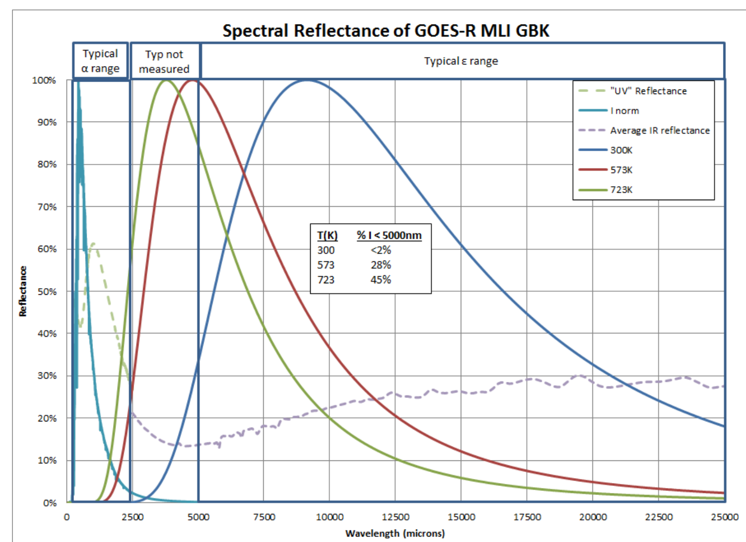
Spectral Measurements

- Reflectance data measurements were repeated to include the "gap region" of 2500-5000nm and plotted with:
  - ATSM E-490 Solar spectral distribution
    - 250 – 2500nm
  - IR spectral distribution (% < 5000nm)
    - Standard (300° K): 2%
    - BK sink (723° K/475° C): 45%
    - Stamet sink (573° K/300° C): 28%
    - OSR sink (548° K/ 275° C): 25%
- Corrected emittances for hot sinks:
  - OSRs: 0.75 (vs 0.79)
  - BK: no correction
  - Stamet: 0.96 (vs 0.90)
    - Affects MLI outer layer; very little effect on SC h/w.

LL 4

Need to "adjust" to account for more complete measurements that were needed due to the Planck effect from the high temperature watrods.
This is shown to be ~2.5° C difference in radiator temperatures.





Watrod Characterization Test

- Completed as part of the pre-SCTV chamber certification (had just completed refurbishment) and MGSE bakeout, just prior to SCTV.
- Goals included
  - Verify new shrouds, command and control system
  - Verify watrod sink temperatures, along with preliminary power supply settings
  - Measure discrete watrod surface temperatures.
  - Bakeout non-flight MGSE
- Used a “SC Simulator” to ensure no zone “cross-talk” from one side to the other
  - Simple Aluminized Kapton rectangular cross-section “blocker”

Watrod Characterization Test - Results

Table 1. Characterization Test Sink Temperatures (Achieved vs Goals)

Sink Temperatures in Characterization Test "Hot" "Warm" "Cold"

Watrod Zone	Thermal Control	Goal WSEOL	Goal SSEOL	Goal AEBOL	Goal TOSP	Measured WSEOL	Measured SSEOL	Measured AEBOL	Measured TOSP	Delta WSEOL	Delta SSEOL	Delta AEBOL	Delta TOSP
+X	MLI	45	-120	-175	-100	43.4	-117.6	-130.8	-136.6	-1.6	2.4	44.2	-36.6
-X	MLI	-175	45	-175	-100	-96.4	52.2	-115.8	-117.3	78.6	7.2	59.2	-17.3
+Y	OSR	-30	-110	-110	-175	-26.7	-105.3	-108.2	-136.2	3.3	4.7	1.8	38.8
-Y	OSR	-175	-60	-175	-175	-117.4	-57.8	-150.6	-153.1	57.6	2.2	24.4	21.9
+Z	MLI	45	-175	-175	-175	43.6	-92.1	-119.1	-125.6	-1.4	82.9	55.9	49.4
-Z	MLI	-100	45	-100	-100	-73.9	42.7	-102.3	-118.6	26.1	-2.3	-2.3	-18.6
Battery -Y	OSR	-175	-60	-175	-175	-121.4	-58.9	-140.8	-145.7	53.6	1.1	34.2	29.3
GLM Radiator +Y	OSR	-40	-120	-120	-175	-39.1	-115.7	-116.1	-156.8	0.9	4.3	3.9	18.2
ABI Radiator -Y	OSR	-175	-70	-175	-175	-91.2	-68.3	-146.6	-150	83.8	1.7	28.4	25.0

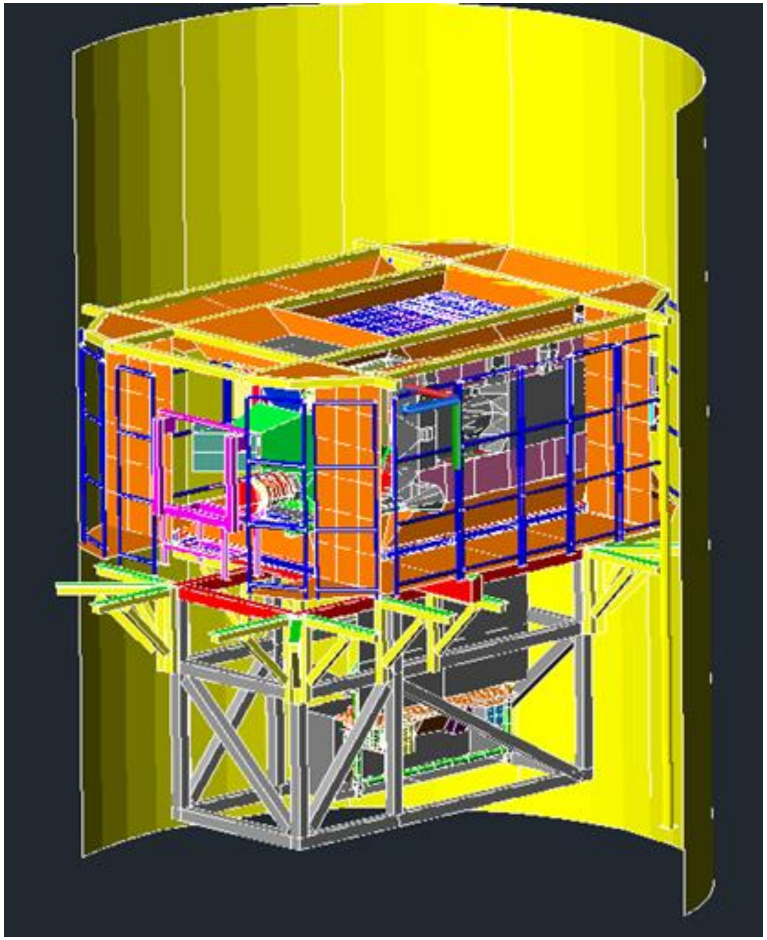
- Most significant finding was the inability to achieve any of the very cold sink temperatures (-175° C highlighted in blue) with most being 24° - 84° C too warm
- Possible causes of this include
  - significant MGSE blockage of the view to the cold shrouds,
  - the coupon error as discovered in the engineering testing, and
  - “cross-talk” between watrod zones, or some combination of these effects.
- Of these, the coupon error is the most critical to understand since it results in a false sink temperature measurement, while the other ones result in a real impact to the sink being measured

GOES-R Thermal Models

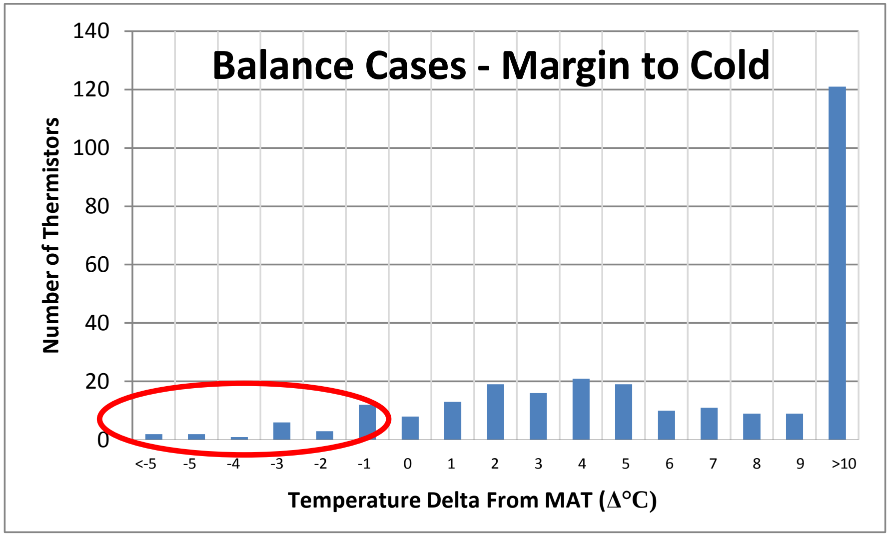
- Instruments: detailed and reduced models required.
  - Reduced models are delivered to NASA and provided as GFE to SC team and used for post-design mission and launch analysis.
- Spacecraft: both integrate reduced instruments
  - Detailed Integrated Spacecraft Model (DISTM)
  - Reduced Integrated Spacecraft Model (RISTM)
- During development, DISTM became so large, it was separated into 3:
  - DISTM SC bus and nadir deck, EPP, GLM, ABI, IMU,ST
  - SWSTM solar wing with SPP, EXIS,SUVI
  - PSTM detailed propulsion: lines, valves, etc

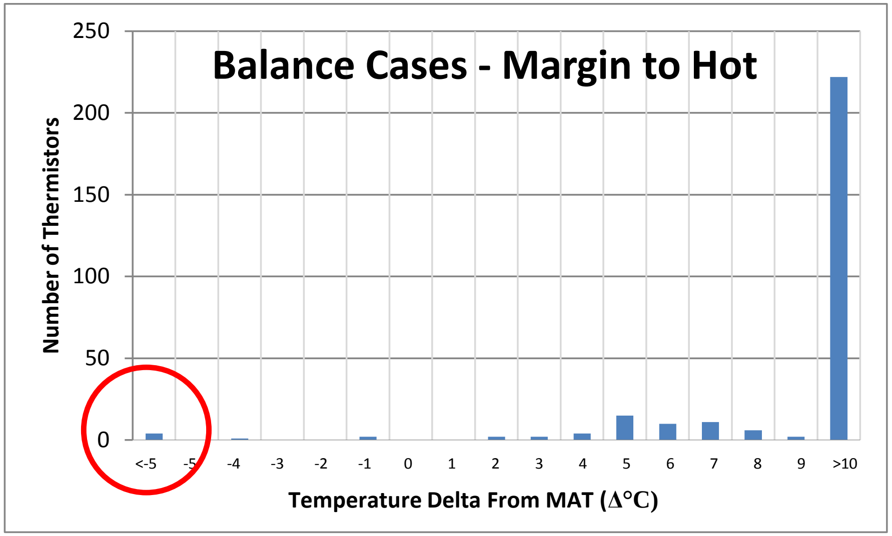
Pre-Test SC Model & Analysis

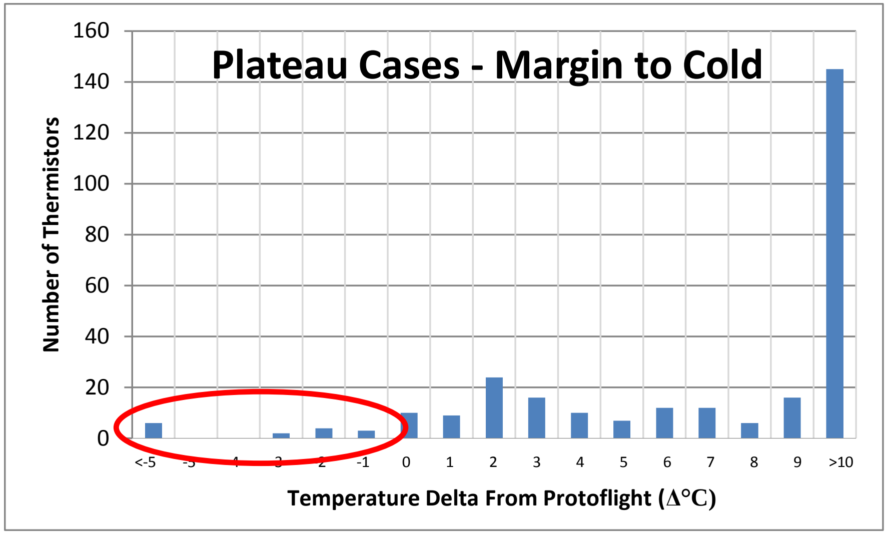
- Mission thermal model RISTM modified for SCTV, including:
  - Configuration: SA, AWA,
  - MGSE: major fixtures modeled
  - Add sink “targets” representing watrod sink zones
- PISTM uses RISTM panel temperatures as boundaries, and sinks for thrusters.
- Compare pre-test thermal balance predictions to Mission Allowable Temperature (MAT) for same cases
- Compare pre-test hot & cold plateau predictions to unit proto-flight limits

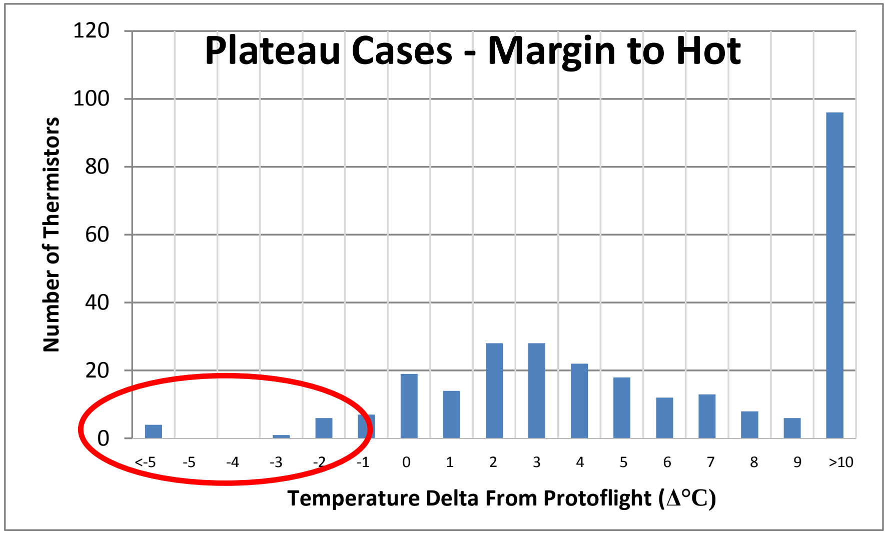


Margins to Limits - Overall







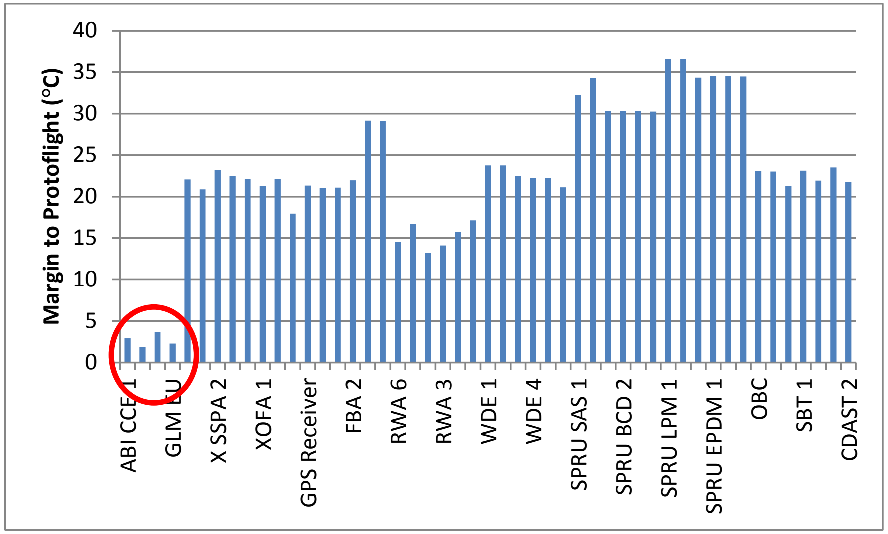


Limiting items

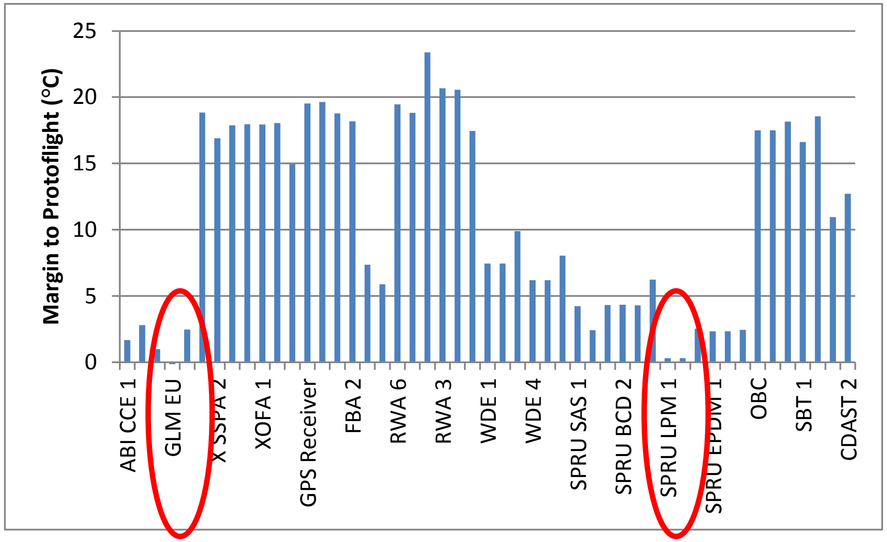
Margins to Protoflight Limits

MY Panel Components

Cold Plateau



Hot Plateau

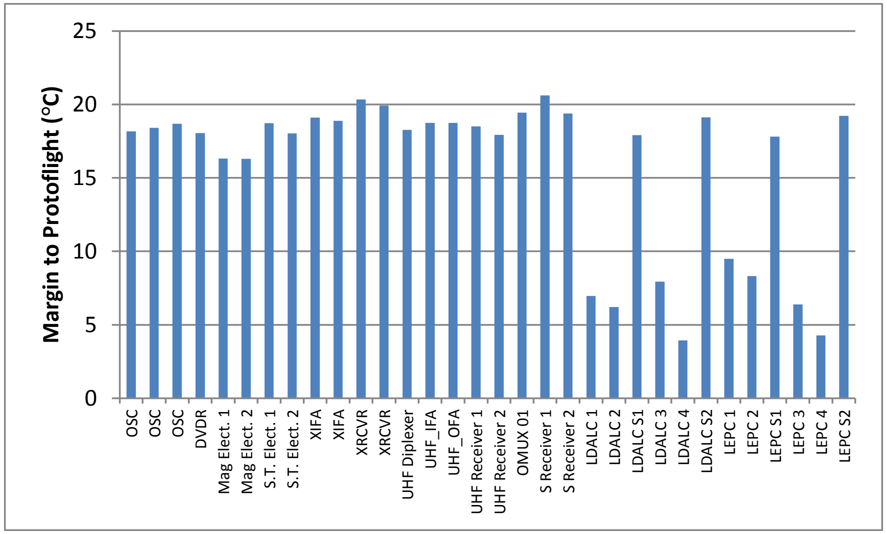


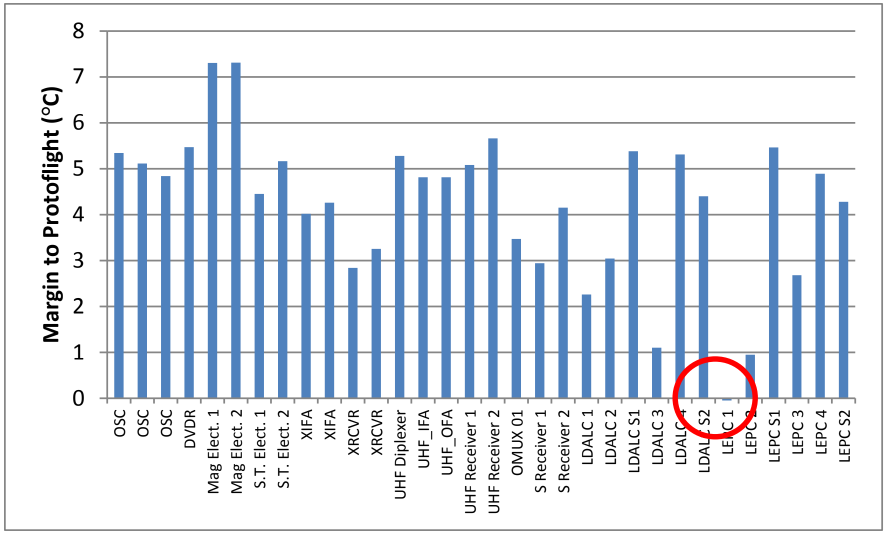
Margins to Protoflight Limits

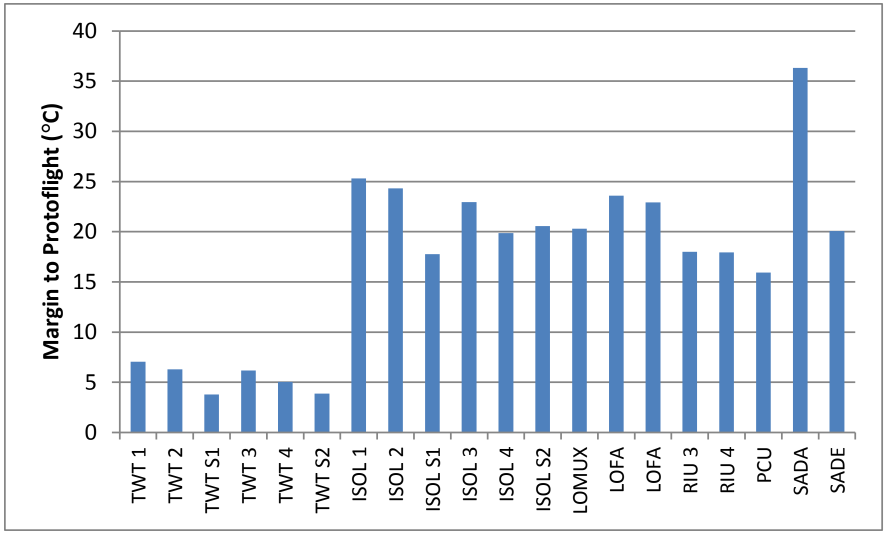
PY Panel Components

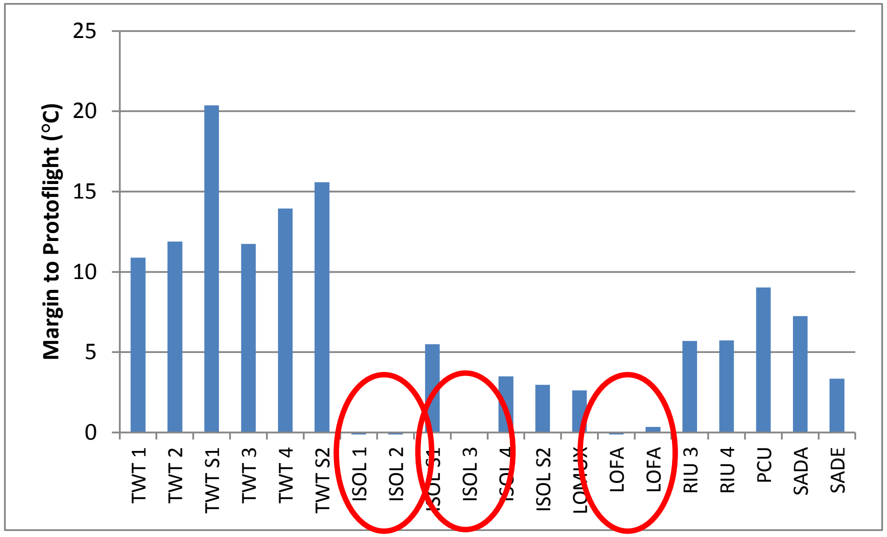
Cold Plateau

Hot Plateau







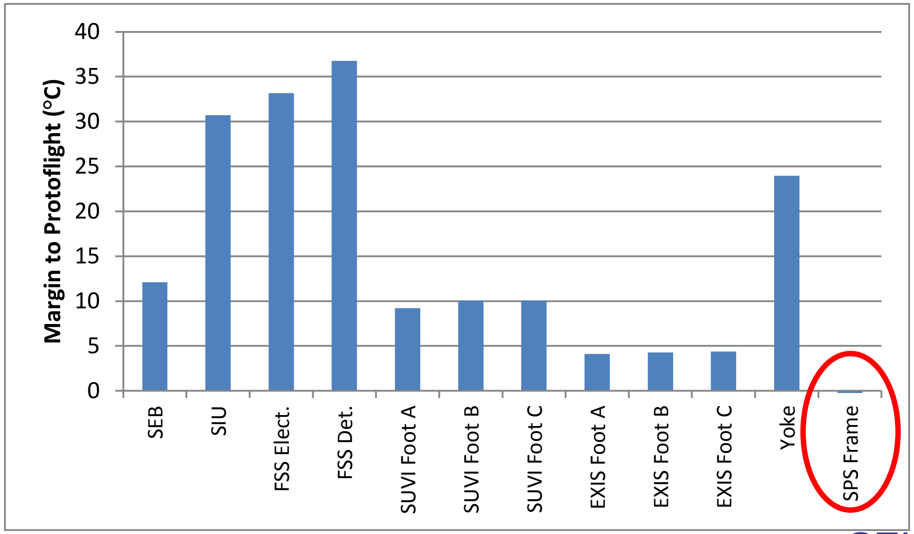


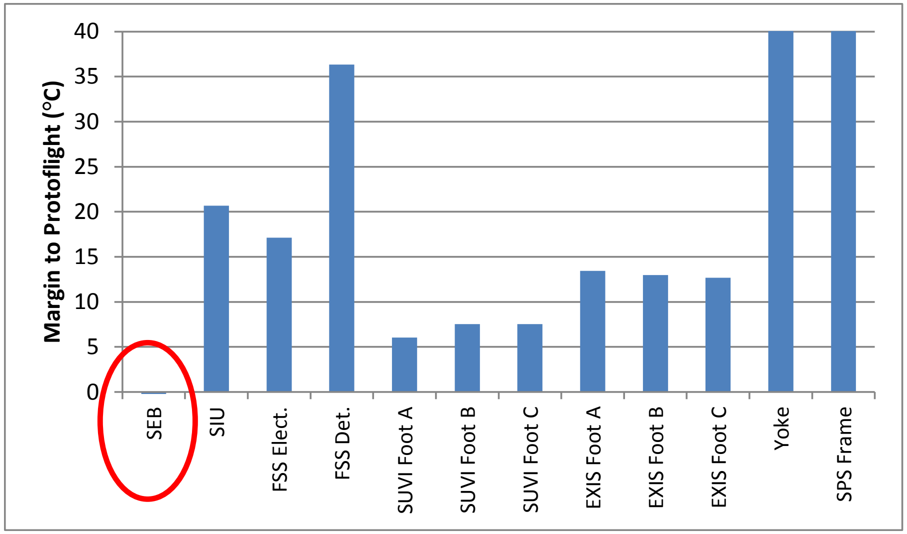
Margins to Protoflight Limits

SWS Components

Cold Plateau

Hot Plateau





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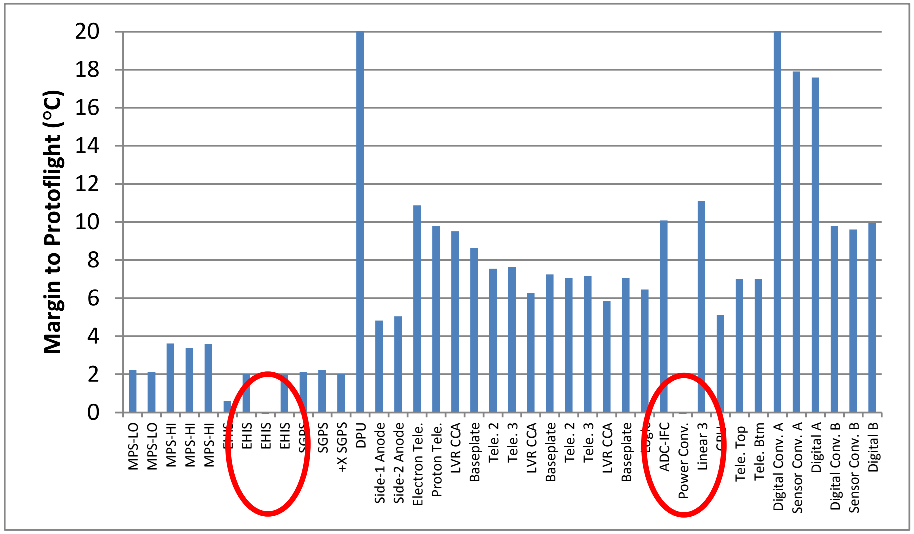
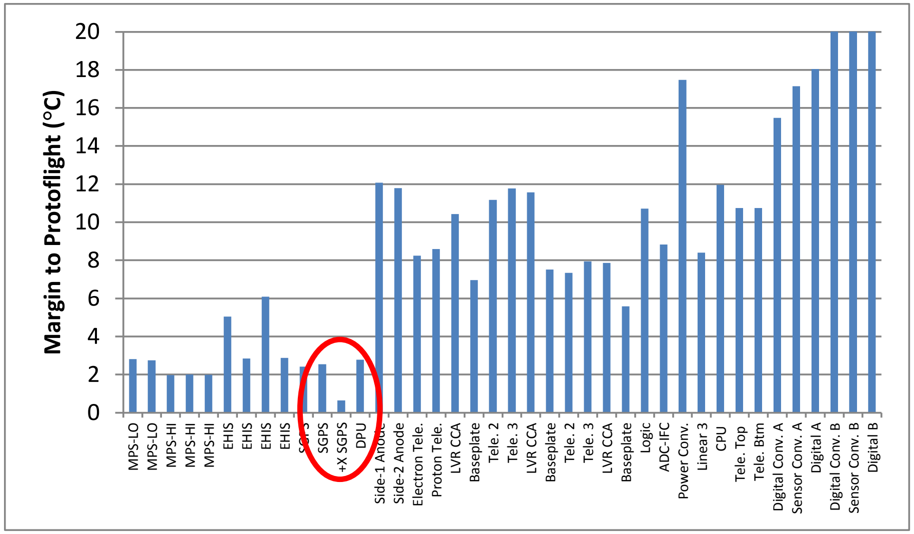


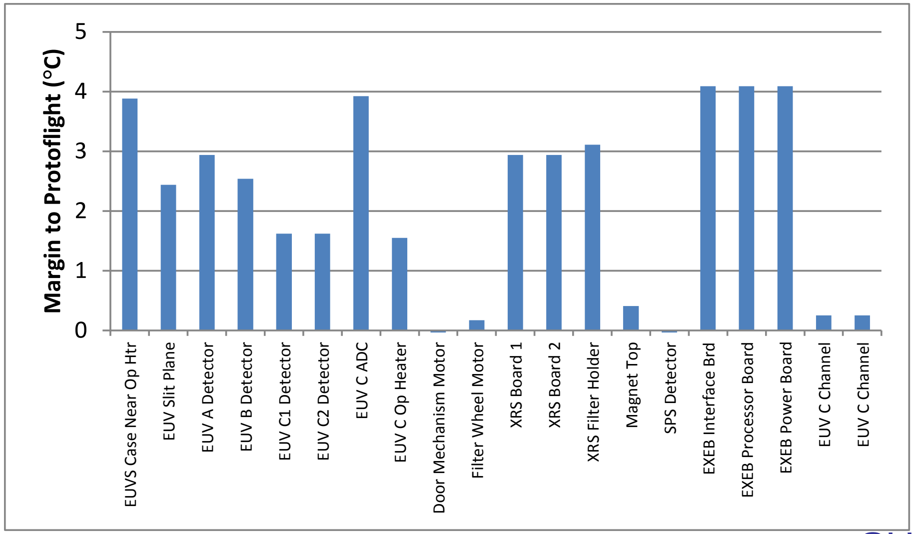


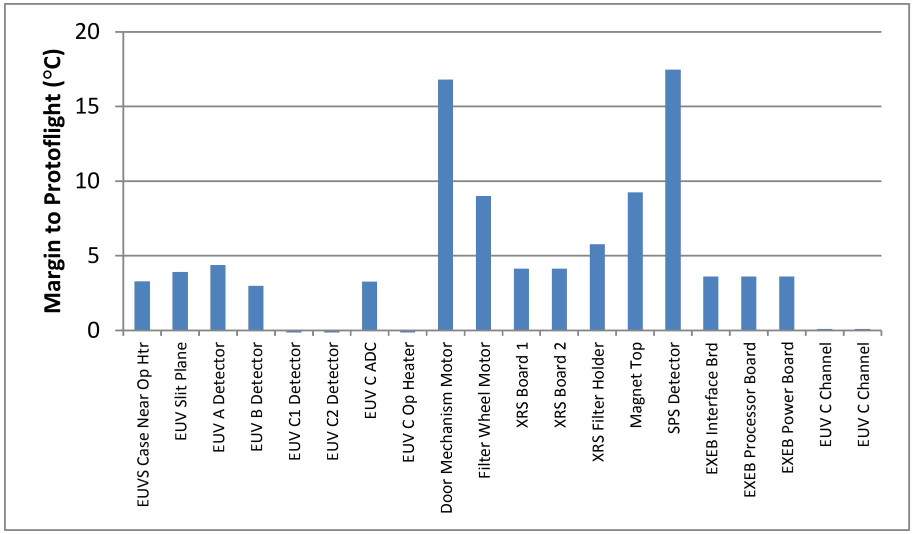
Margins to Protoflight Limits

EXIS

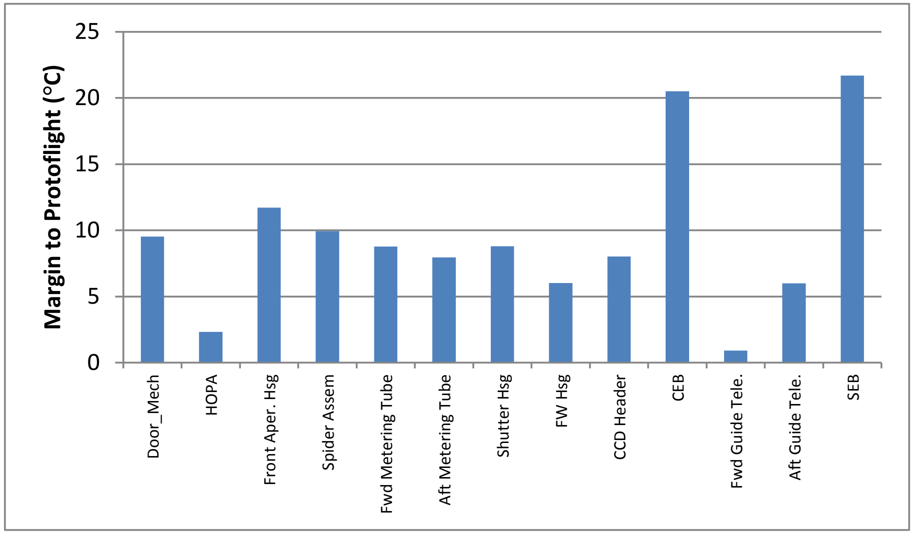
Cold Plateau

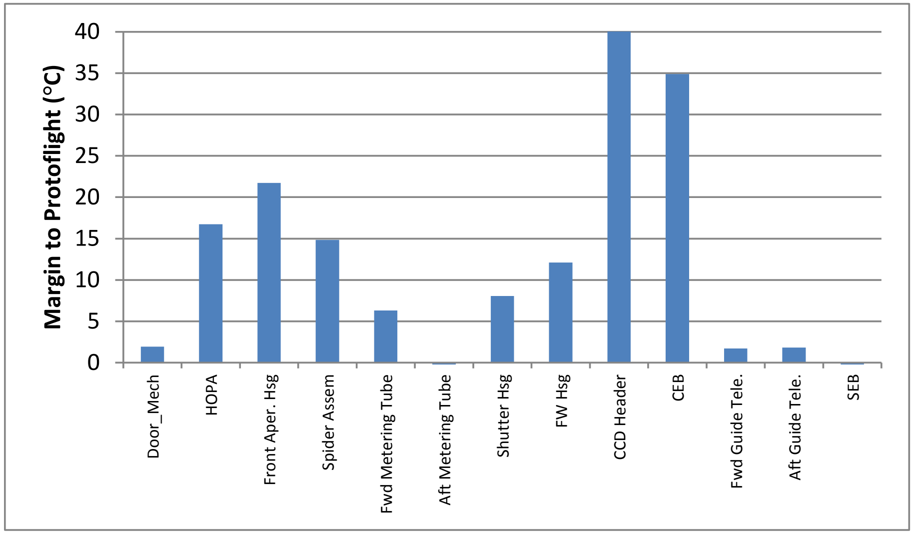
Hot Plateau





SUVI



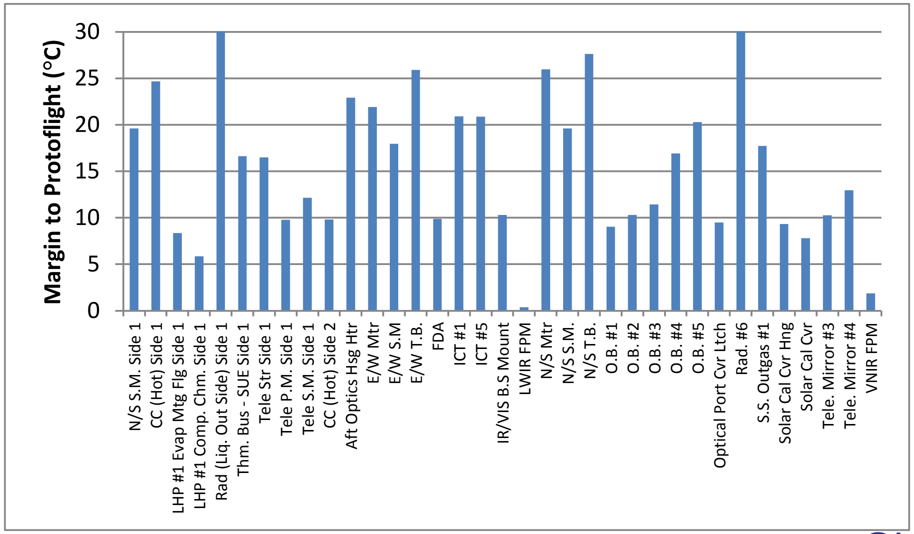


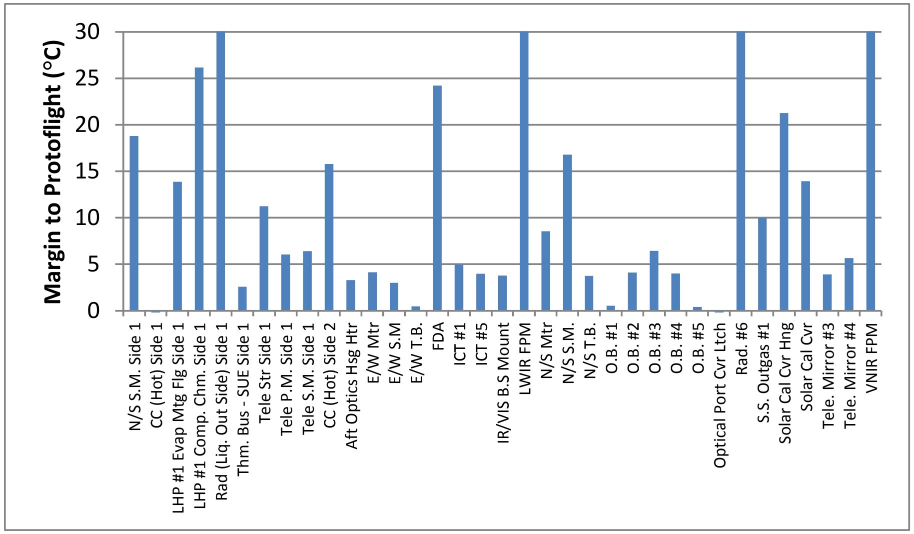
Margins to Protoflight Limits

ABI

Cold Plateau

Hot Plateau





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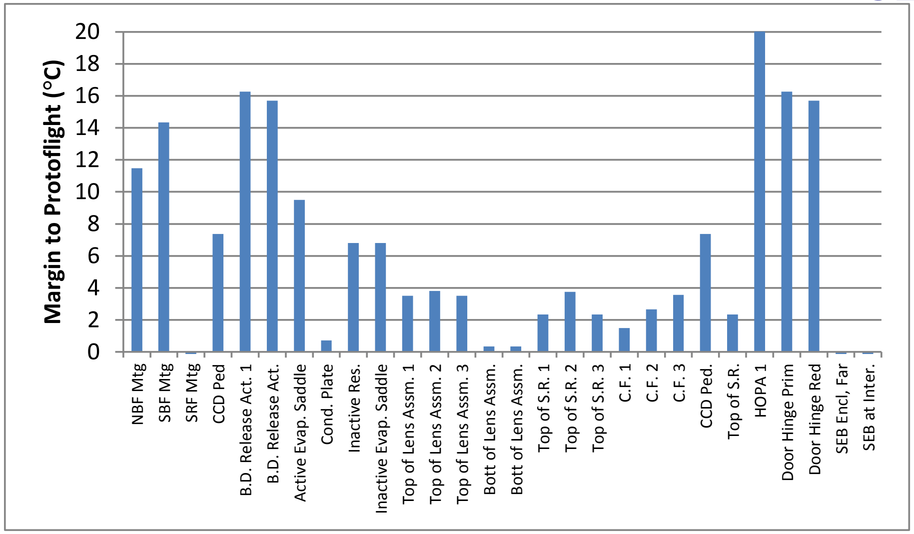
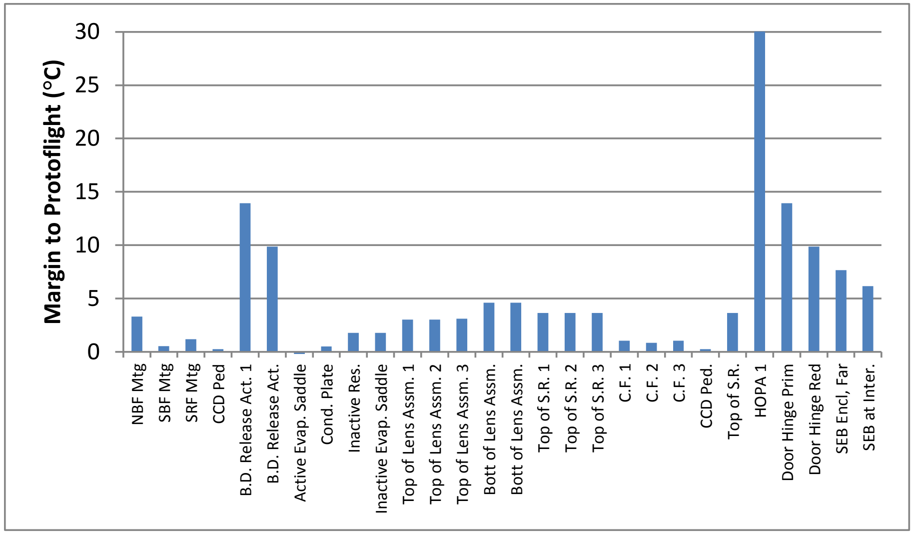
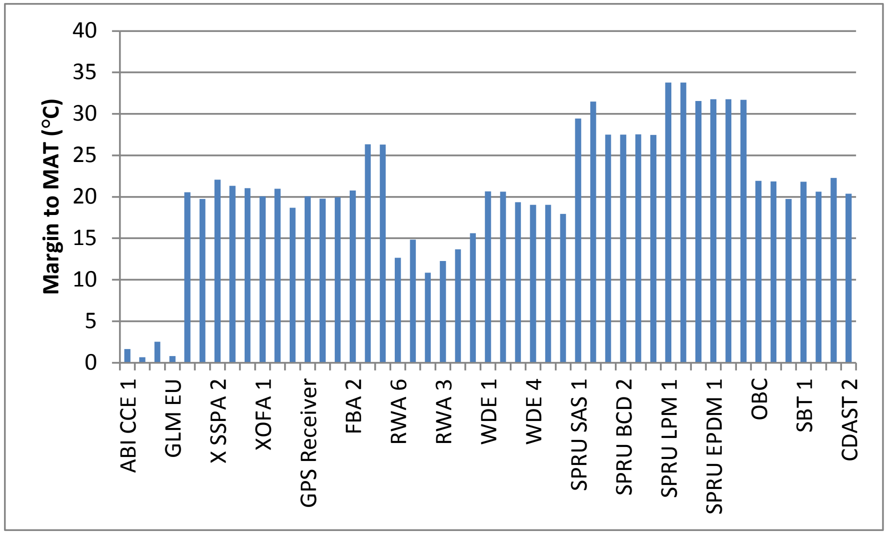




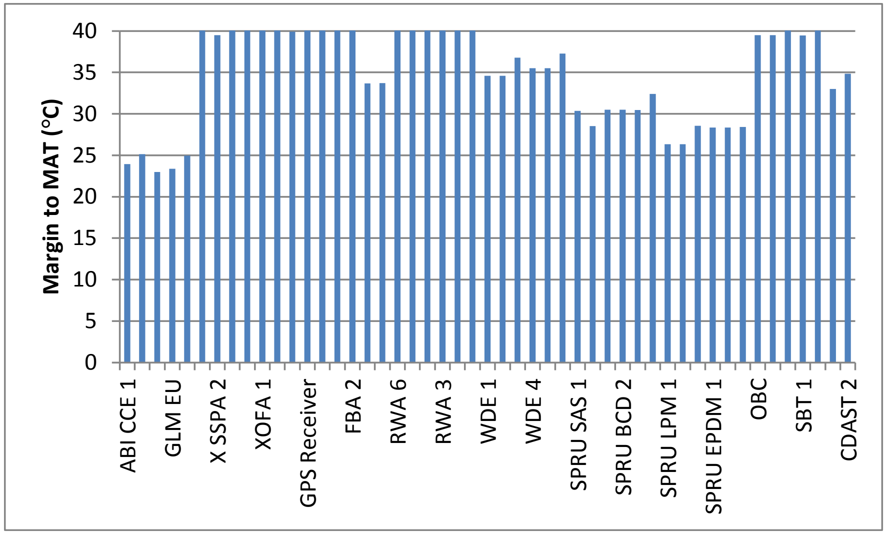
Balance – Margin to MAT

MY Panel Components

Cold Balance



Hot Balance

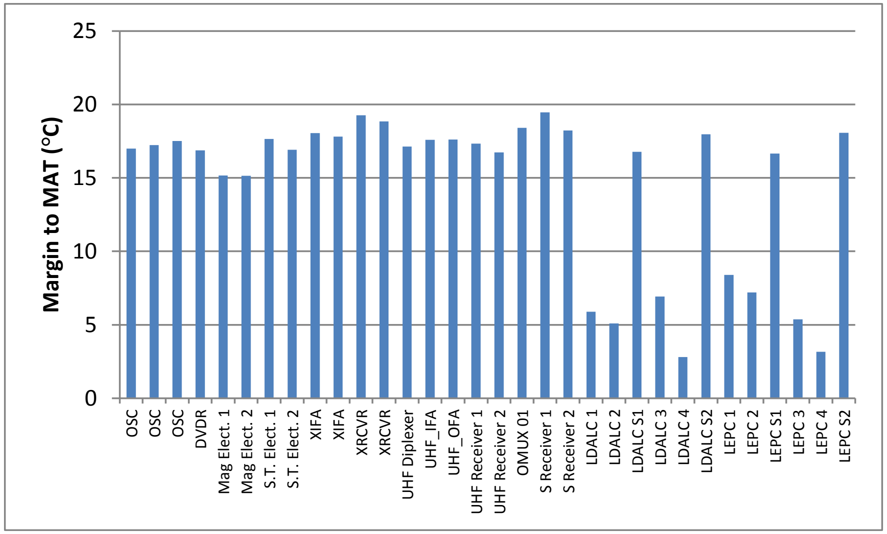


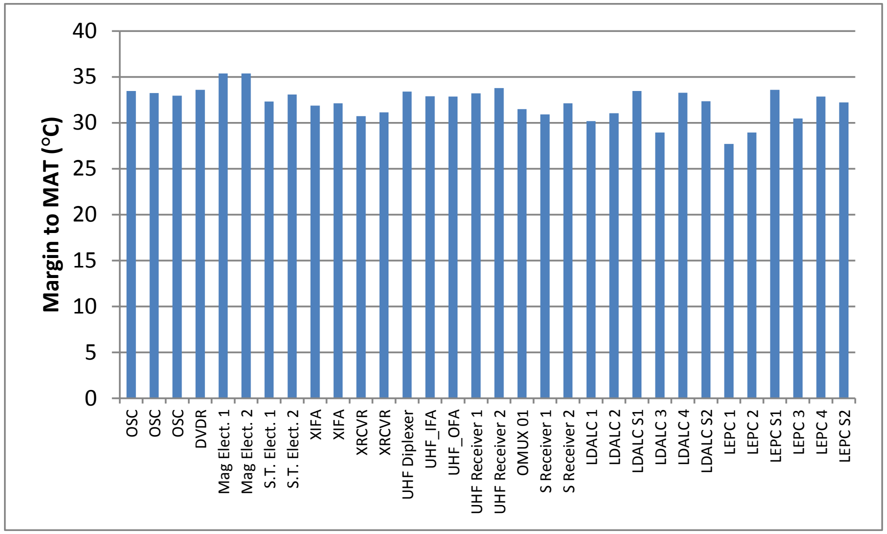
Balance – Margin to MAT

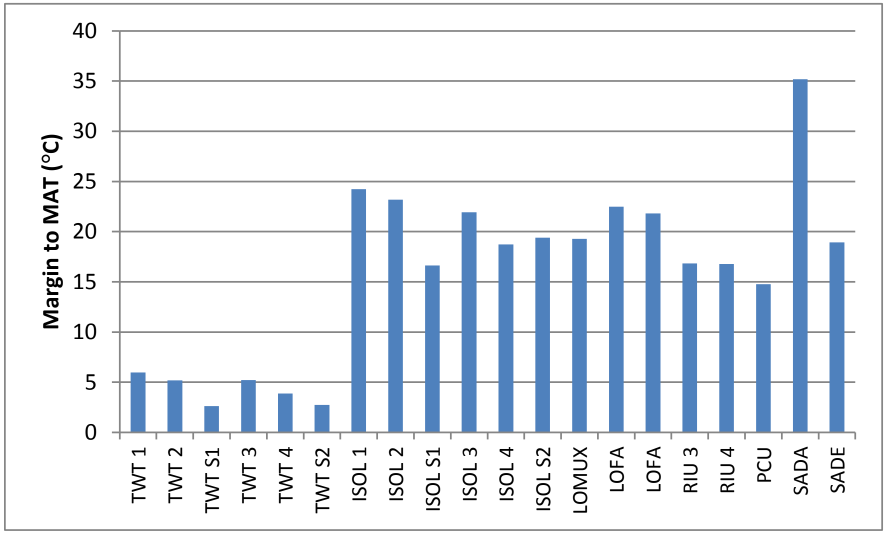
PY Panel Components

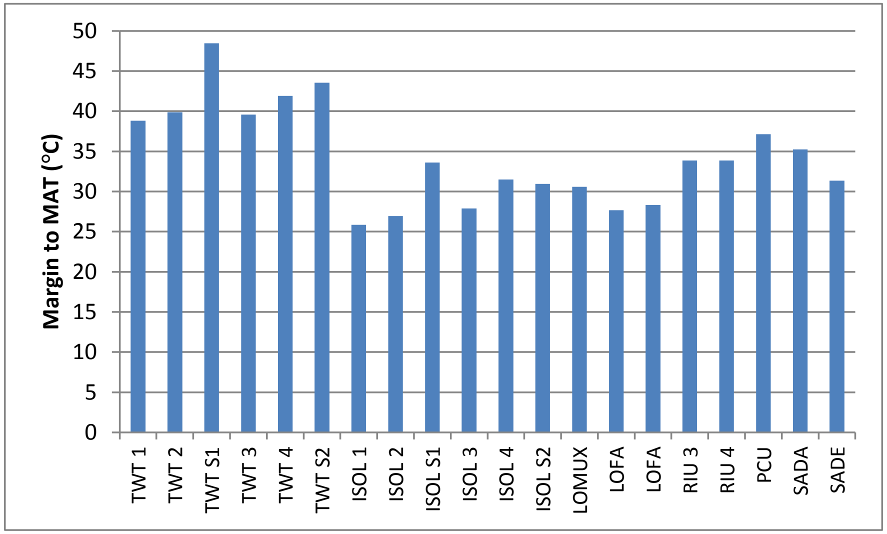
Cold Balance

Hot Balance





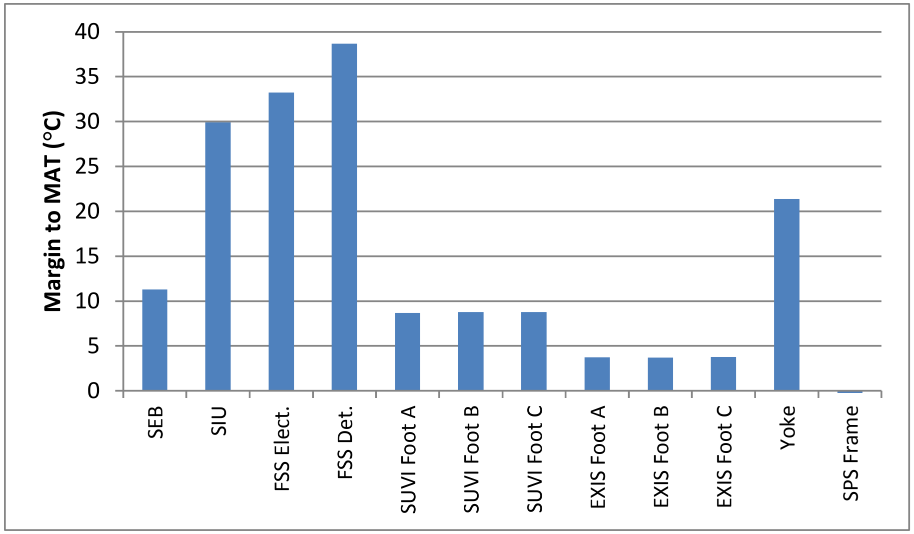




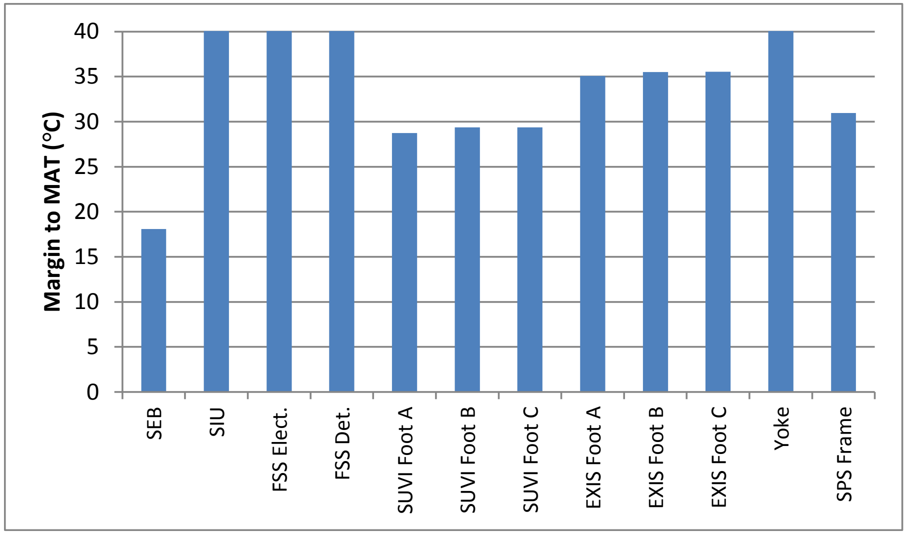
Balance – Margin to MAT

SWS Components

Cold Balance



Hot Balance



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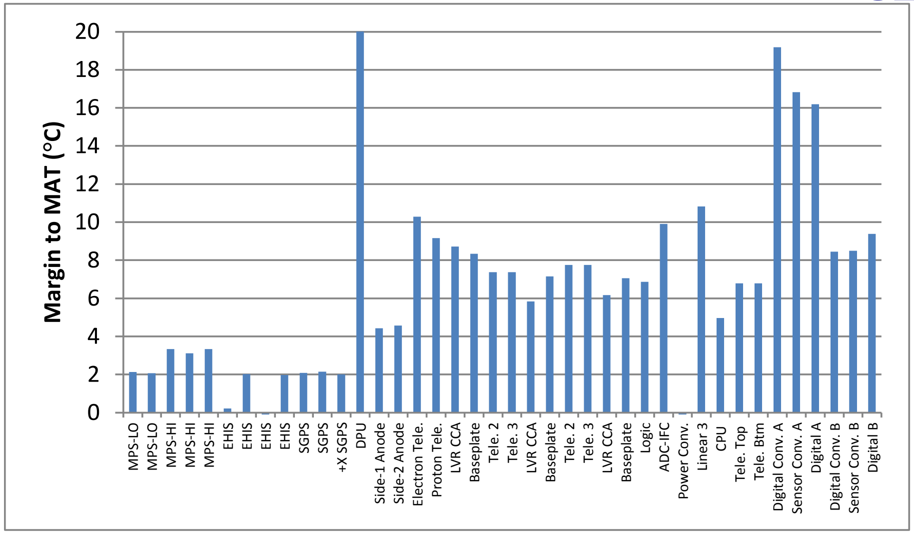
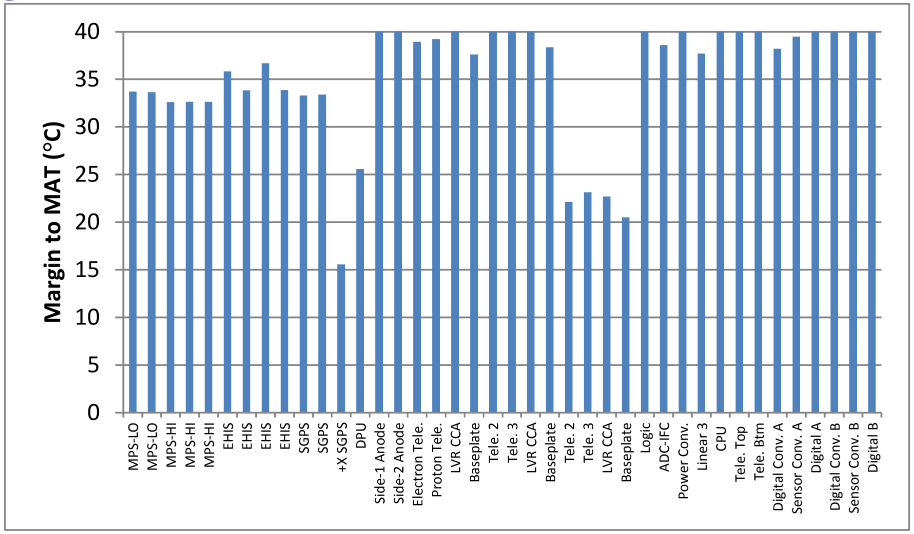
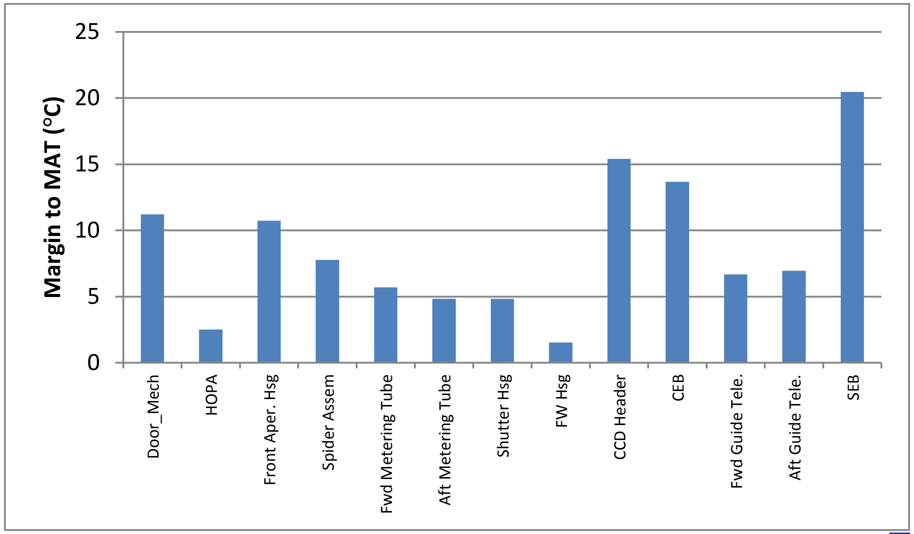




Balance – Margin to MAT

SUVI

Cold Balance



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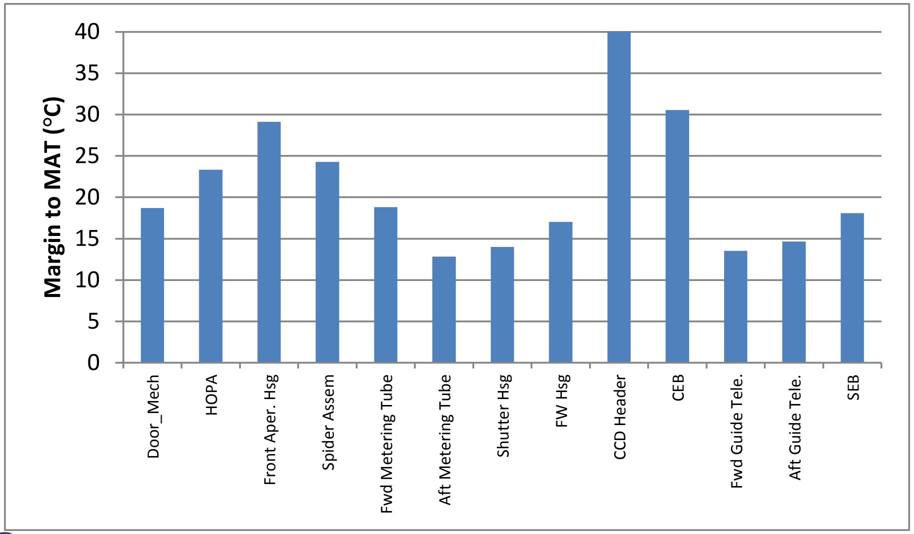

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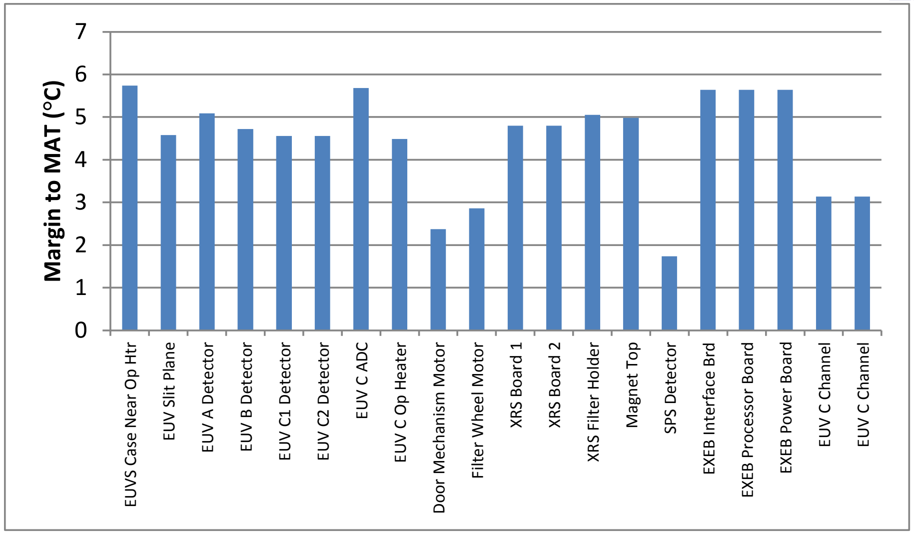
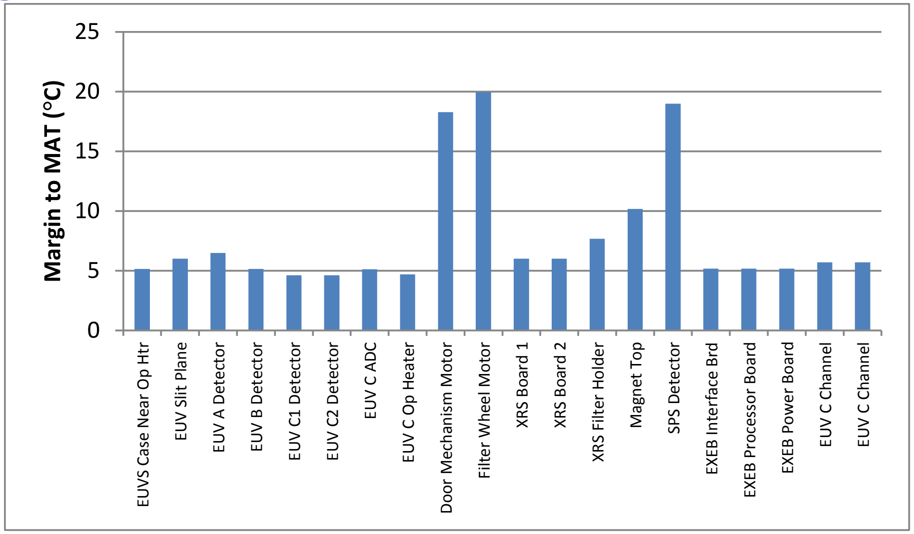


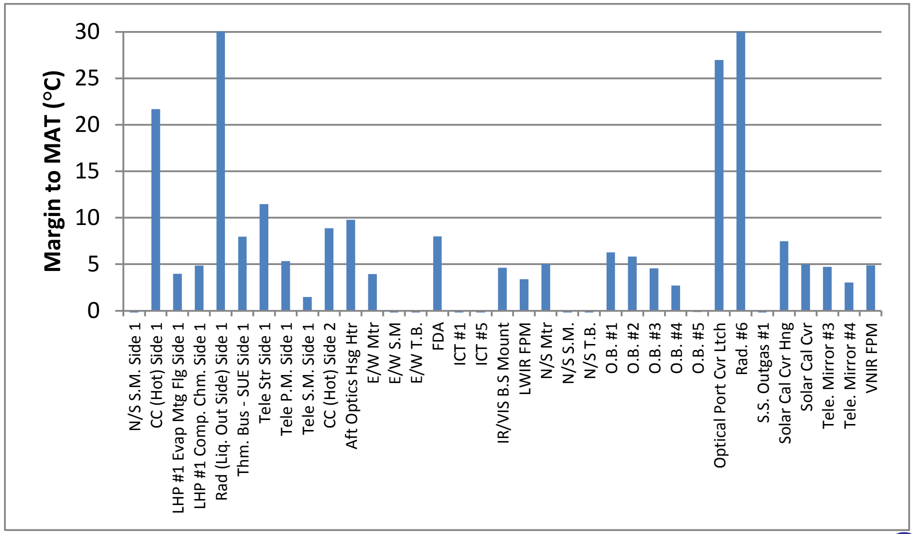


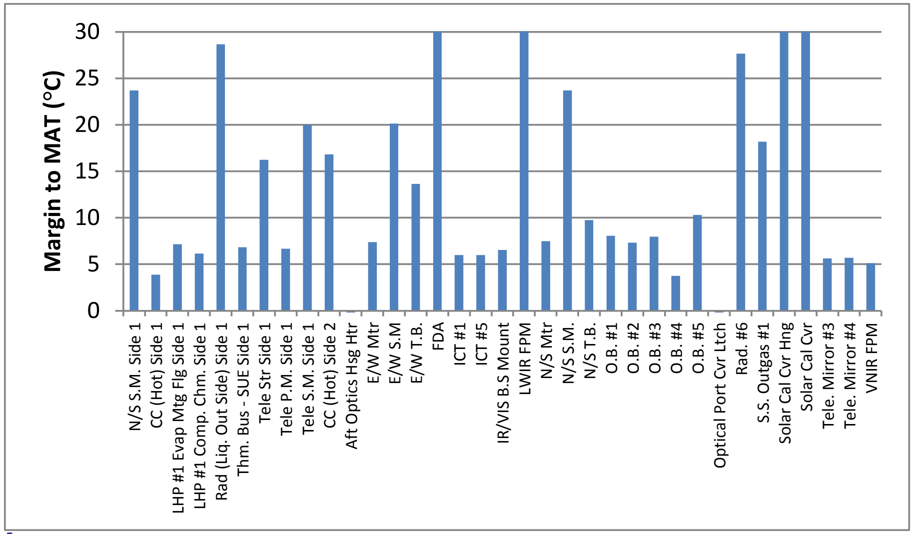
Balance – Margin to MAT

ABI

Cold Balance

Hot Balance





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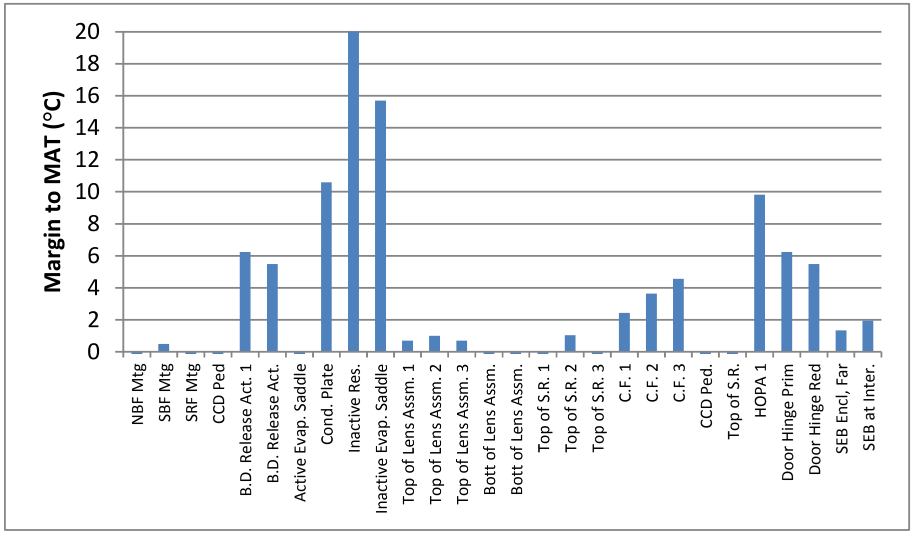
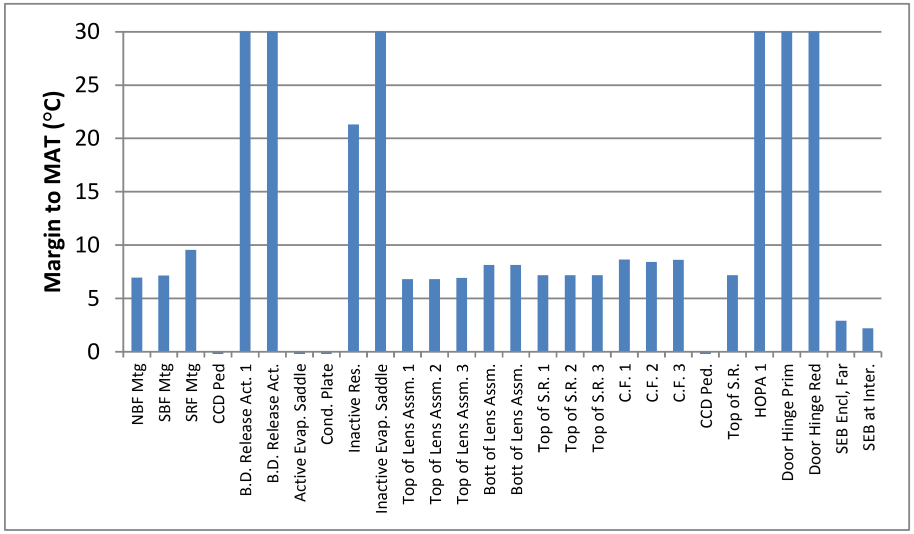
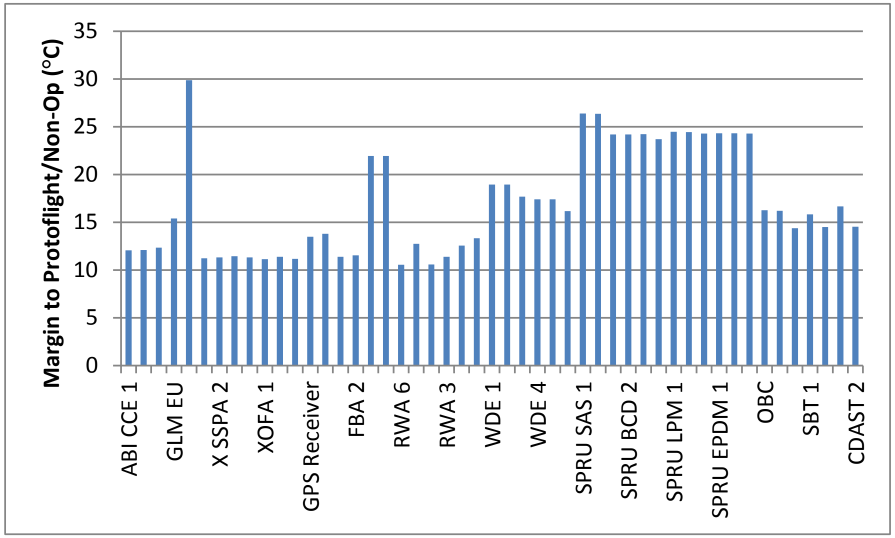


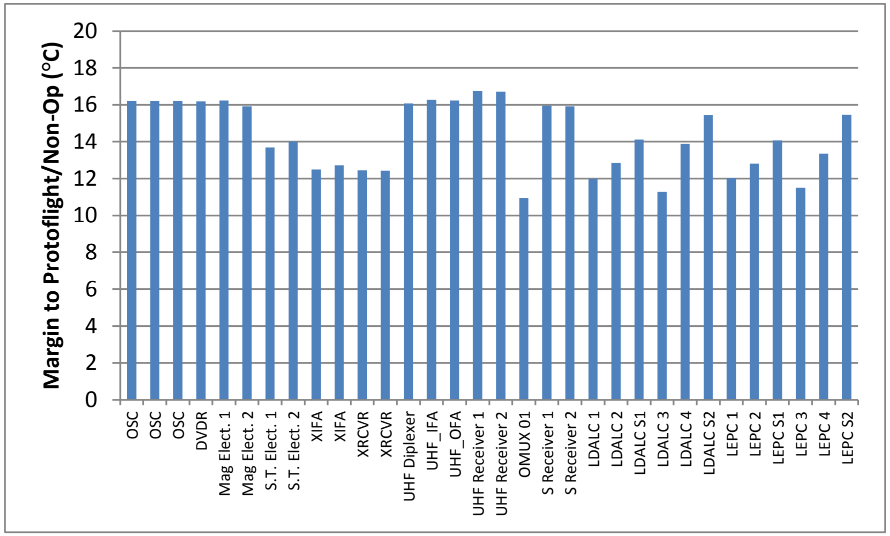


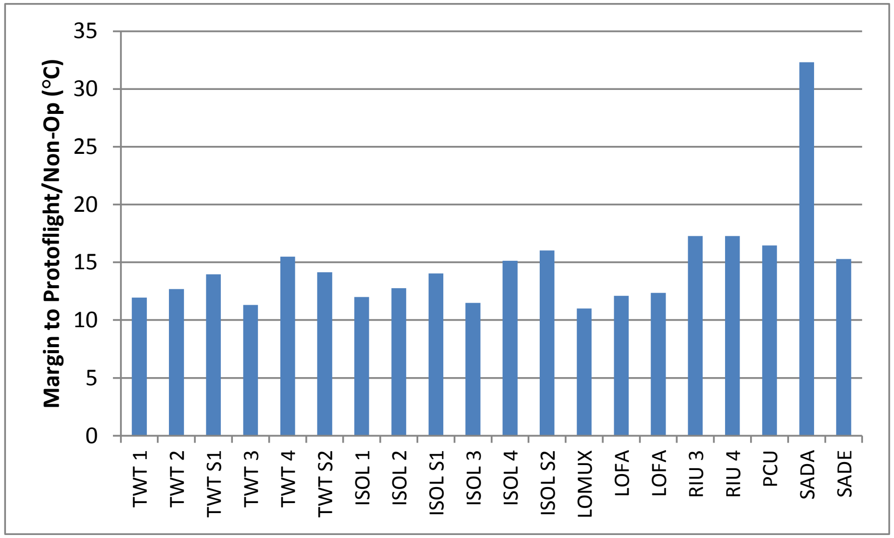
TOSP– Margin to Protoflight/Non-Op

MY Panel Components



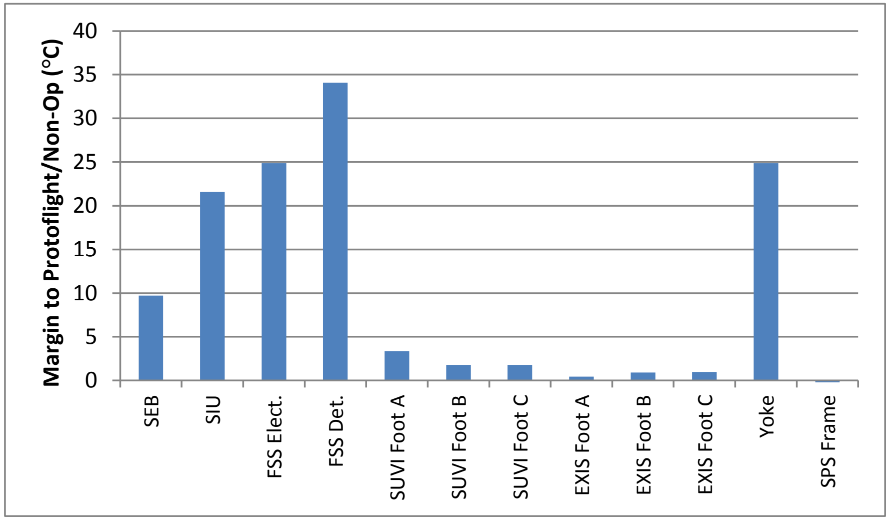
PY Panel Components



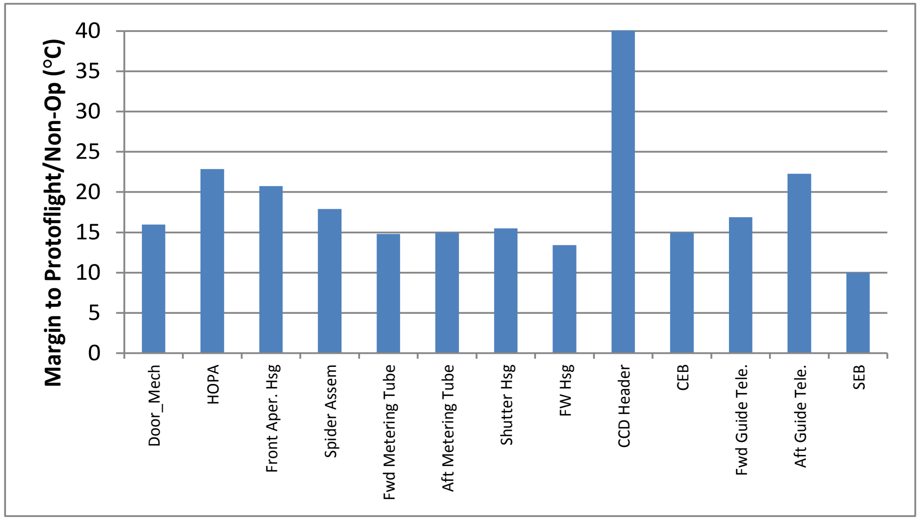


TOSP– Margin to Protoflight/Non-Op

SWS Components



SUVI



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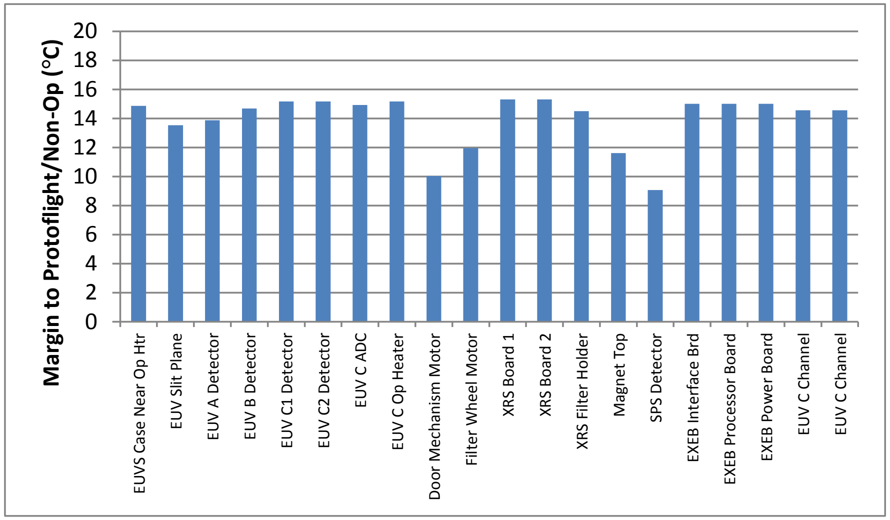

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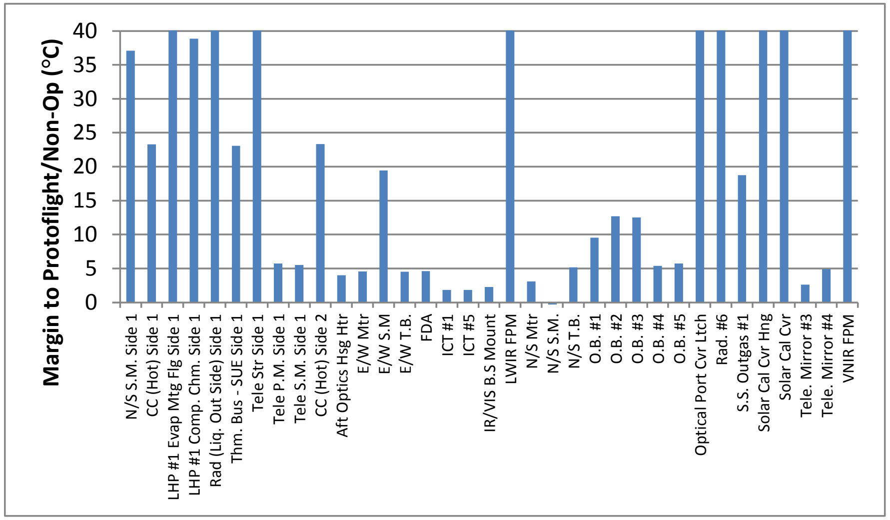
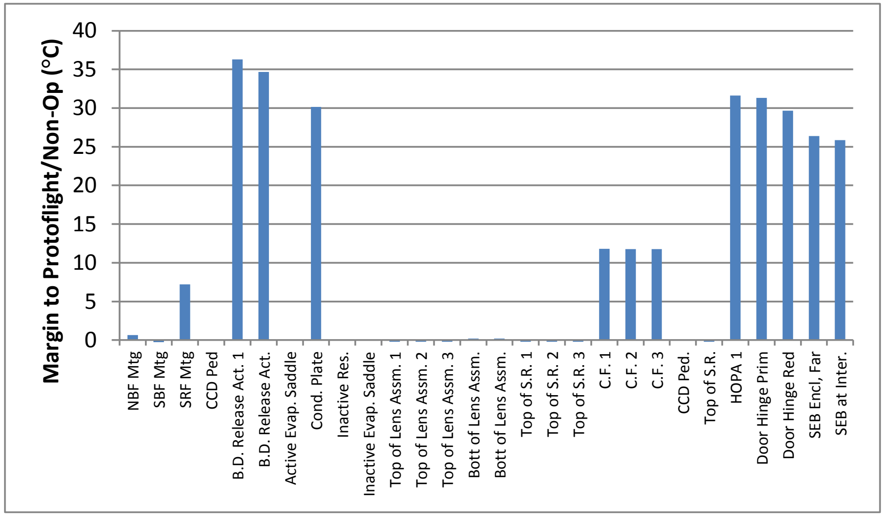
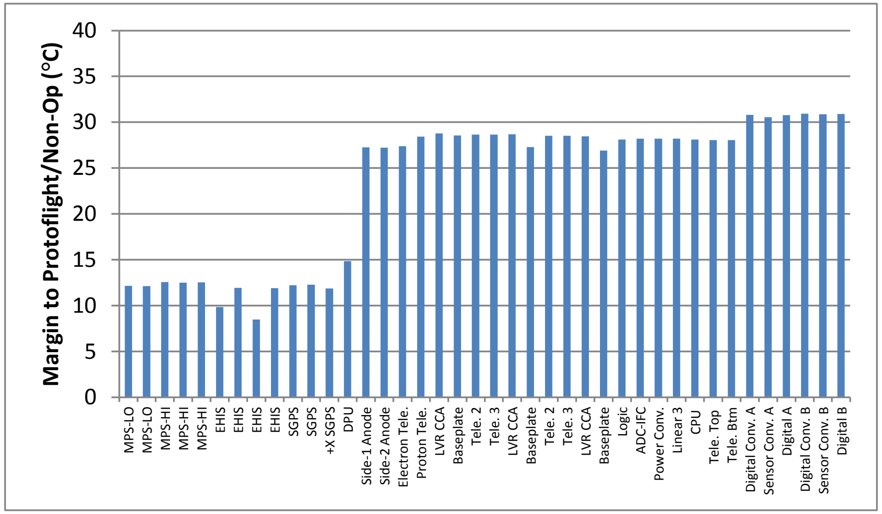


TOSP– Margin to Protoflight/Non-Op

GLM



SEISS



Pre-SCTV Conclusion/Summary

- GOES-R SCTV preparations spanned ~ 12 months leading up to the test, in parallel with I&T activities.
- Watrods provide better hot-cold simulation than heater plates, and can be “simpler” than coldplates.
- Using watrods for environmental simulation requires significant effort to mitigate potential issues.

Post-SCTV Analysis

Quick-Look Results

Correlation

SCTV Results

- Spacecraft Thermal Vacuum (SCTV) Overview
  - Test Flow/Profile; Summary of dates/durations
  - Quick-Look Results (update spreadsheet for Cycle 4 !!)
- Post-Test Correlation Analysis
  - Model correlation
    - “Quick-look” report
    - Dissipation update
    - Sink measurement error
- Conclusions/Summary

Thermal Balance Cases in SC TVAC

- Three balance cases performed
  - Hot: Winter Solstice at End Of Life (WSEOL)
  - Hot: Summer Solstice at End Of Life (SSEOL)
  - Cold: Autumnal Equinox at Beginning Of Life (AEBOL)
- Thermal balance declared when:
  - a) Spacecraft temperatures change less than 0.5° C/hour for 3 hours
  - b) Spacecraft temperatures have a decreasing slope over 3 hour dwell
  - c) Spacecraft temperatures are within 2° C of projected steady state temperature
- Target cold sinks not achieved
  - Spacecraft dissipated between 2.8 kW and 3.7 kW of heat (depending on case)
  - MGSE deposited over 36 kW of heat into chamber during hot thermal balances (WSEOL/SSEOL) and over 10 kW during cold balance (AEBOL)
- Equipment dissipations much less than expect (explained further in correlation section)
- Balance data used to correlate thermal models

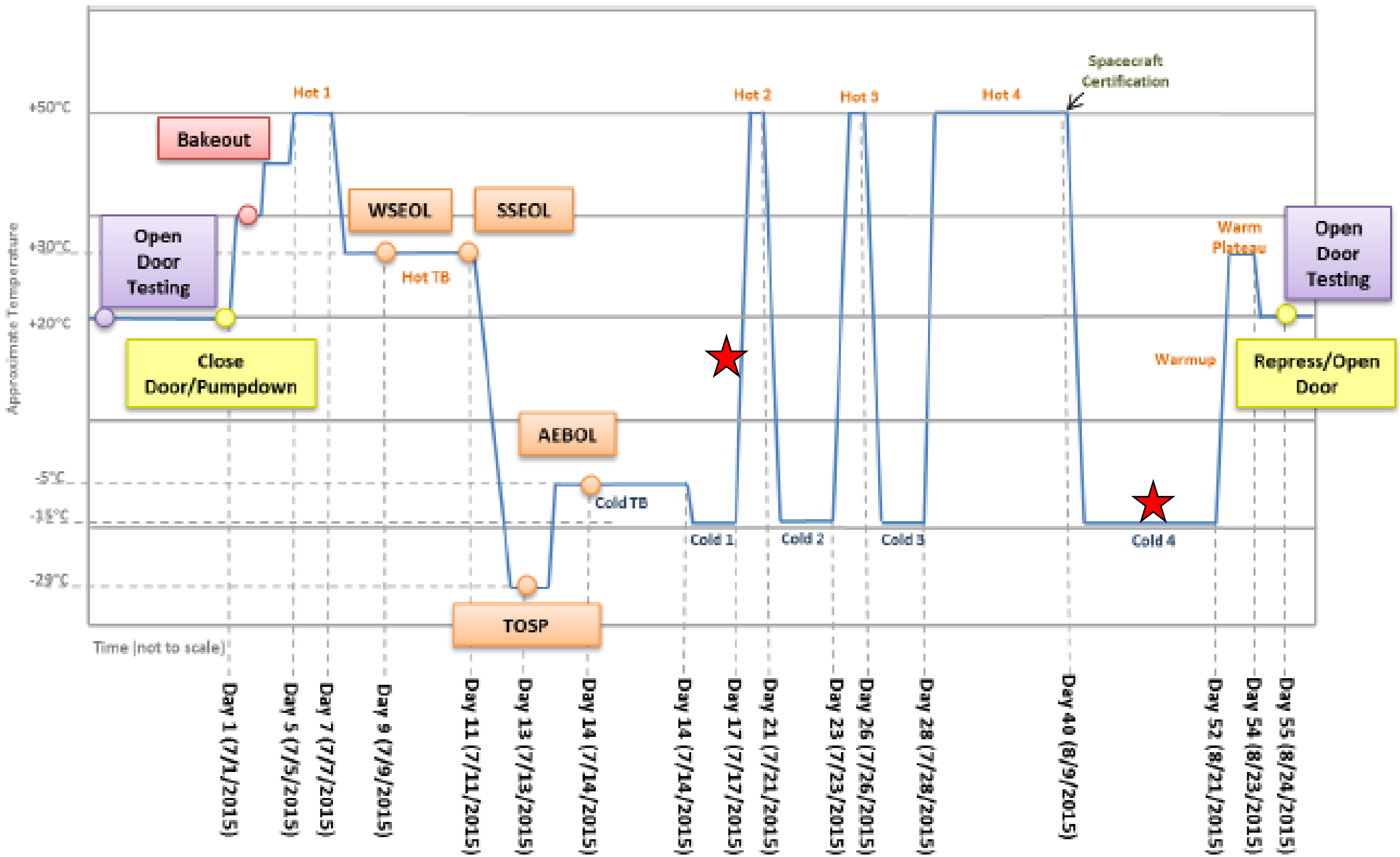
Equivalent Sink Detectors (ESDs)

- Used modified MLI blankets with TCs to measure sink temperatures
- Discovered ESDs not completely adiabatic during TVAC
  - Back loading from radiator seen in ESD temperature readings
  - Resulted in slightly warm biased sink temperature readings
- NASA Goddard performed test to characterize temperature offset
  - “Decoder ring” created to calculate actual temperature from measured
  - Only detectors near heat-dissipating areas of S/C affected

Zone	WSEOL (°C)			SSEOL (°C)			AEBOL (°C)		
	Target	Measured	Adjusted	Target	Measured	Adjusted	Target	Measured	Adjusted
MX	-175	-100.9	-100.9	30	32.1	32.1	-175	-110.5	-110.5
PX	45	29.6	29.6	-120	-106.6	-106.6	-175	-118.1	-118.1
MY	-175	-71.5	**-78.4**	-60	-54.6	**-59.0**	-175	-72.6	**-79.7**
PY	-30	-24.7	**-27.1**	-110	-89.1	**-99.7**	-110	-92.1	**-103.5**
MZ	-100	-59.4	-59.4	45	47.0	47.0	-100	-71.3	-71.3
PZ	45	41.2	41.2	-175	-101.7	-101.7	-175	-127.4	-127.4
ABI	-123	-91.0	**-94.3**	-70	-62.8	**-63.6**	-175	-101.2	**-105.7**
GLM	-40	-40.5	**-43.4**	-120	-81.5	**-90.2**	-120	-84.7	**-94.2**
Battery	-175	-82.8	**-93.8**	-60	-56.1	**-61.9**	-175	-83.2	**-94.3**
SEISS	-140	-101.2	**-115.4**	-55	-59.8	**-64.8**	-80	-77.5	**-82.5**

SCTV Profile

★ Interesting event…….



SCTV Timeline

- Door closed: 07/02/2015
- Door opened: 08/24/2015
- Total Duration: 54 days
  - Balance plateaus: 7 d
  - Hot plateaus: 12.5 d
  - Cold plateaus: 13.7 d

Test Milestone	Start (UTC)	End (UTC)
Close door/Pump down	7/1/2015 18:10	7/2/2015 18:55
Ramp shroud cold	7/2/2015 18:55	7/2/2015 21:50
Bakeout (35°C)	7/4/2015 4:42	7/4/2015 7:15
Bakeout (45°C)	7/4/2015 7:15	7/4/2015 11:50
Bakeout (55°C)	7/4/2015 11:50	7/5/2015 7:40
Transition to Hot 1	7/5/2015 7:40	7/6/2015 7:25
Hot 1 Plateau	7/6/2015 7:25	7/7/2015 19:39
Transition to WSEOL	7/7/2015 19:39	7/9/2015 9:45
WSEOL (Hot Thermal Balance 1)	7/9/2015 9:45	7/9/2015 16:30
Transition to SSEOL	7/9/2015 19:34	7/11/2015 20:00
SSEOL (Hot Thermal Balance 2)	7/11/2015 20:00	7/11/2015 23:50
TOSP	7/11/2015 23:50	7/13/2015 7:20
Transition to AEBOL	7/13/2015 7:20	7/14/2015 16:00
AEBOL (Cold Thermal Balance)	7/14/2015 16:00	7/14/2015 20:30
Transition to Cold 1	7/14/2015 20:30	7/16/2015 8:30
Cold 1 Plateau	7/16/2015 8:30	7/17/2015 8:42
Transition to Hot 2	7/17/2015 8:42	7/19/2015 23:15
Hot 2 Plateau	7/19/2015 23:15	7/21/2015 0:30
Transition to Cold 2	7/21/2015 0:30	7/22/2015 5:31
Cold 2 Plateau	7/22/2015 5:31	7/23/2015 6:00
Transition to Hot 3	7/23/2015 6:00	7/25/2015 11:40
Hot 3 Plateau	7/25/2015 11:40	7/26/2015 14:00
Transition to Cold 3	7/26/2015 14:00	7/27/2015 21:00
Cold 3 Plateau	7/27/2015 21:00	7/28/2015 21:00
Transition to Hot 4	7/30/2015 3:30	8/1/2015 0:39
Hot 4 Plateau	8/1/2015 0:39	8/9/2015 20:05
Transition to Cold 4	8/9/2015 20:05	8/11/2015 3:10
Cold 4 Plateau	8/11/2015 3:10	8/21/2015 19:25
Transition to Warm Plateau	8/21/2015 19:25	8/22/2015 18:00
Warm Plateau	8/22/2015 18:00	8/23/2015 22:05
Repress/Open Door	8/23/2015 22:05	8/24/2015 16:00

Note: A gap between the end of plateau and beginning of transition signifies a test was performed between the two.

Sink Summary

- Cold sinks were not achievable. Due to:
  – MGSE blockage: this is a real effect
  – zone “cross-talk”: this is a real effect
  – measurement coupon error: this is a false effect
- Coupon “correction” used in correlation analysis.
- Coupon redesign (and retest) for GOES-STU SCTV.

Heater Type	Zone	WSEOL			SSEOL			AEBOL		
		Target (°C)	Measured (°C)	Adjusted (°C)	Target (°C)	Measured (°C)	Adjusted (°C)	Target (°C)	Measured (°C)	Adjusted (°C)
Watrod	MX	-175	-101	-101	30	32	32	-175	-111	-111
	PX	45	17	17	-120	-76	-76	-175	-103	-103
	MY	-175	-76	-84	-60	-62	-67	-175	-79	-88
	PY	-30	-25	-27	-110	-89	-100	-110	-92	-104
	MZ	-100	-59	-59	45	47	47	-100	-71	-71
	PZ	45	38	38	-175	-101	-101	-175	-123	-123
	ABI	-123	-91	-94	-70	-63	-64	-175	-101	-106
	GLM	-40	-41	-43	-120	-82	-90	-120	-85	-94
	Battery	-175	-83	-94	-60	-56	-62	-175	-83	-94
	SEISS	-140	-101	-115	-55	-60	-65	-80	-78	-83

Correlation Metrics & Requirements

- NASA Goddard requires a thermal vacuum test summary before the end of the test.
  - Thermal balance plateau temperatures
  - Thermal cycle plateau temperatures
- The intent of this report it to simply document the thermal results, and establish the beginning point for the thermal model correlation effort.
- GSFC thermal correlation goals: NASA GSFC Thermal Engineering Branch typically uses:
  - Avg Error: ΔT_{AVG}: = +/- 1.0° C
  - Standard Deviation: $\sigma_{\Delta T}$: = 2.5° C
  - Max Error: ΔT_{MAX}: = +/- 5.0° C
- Project requirement: "The RISTM shall be correlated against the system level thermal balance test data to temperatures within 3° C and unit energy balance within 3%."

Looking for Stability

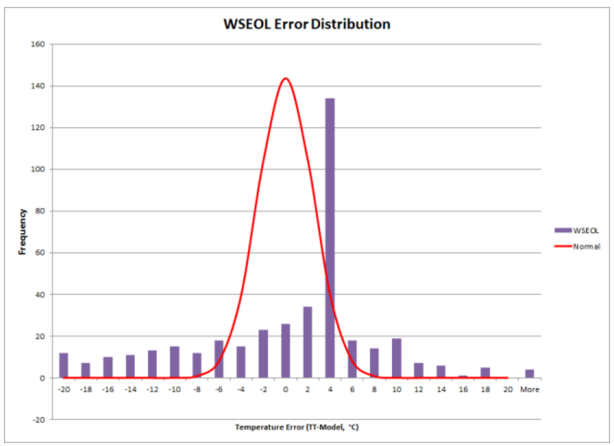
- Ensuring stability when balance is "declared" is key for correlation.
- The GOES-R contract specifies "Thermal Balance stability shall be considered achieved when spacecraft temperatures change less than 0.5ºC per hour for at least 3 hours with a decreasing slope over that 3 hour period and the temperatures are within 2° C of the final projected steady state temperature."
- Stability was monitored during the transitions by importing TC data into a spreadsheet, that automatically calculated dT/dt and T_{EQUIL} for every sensor, using:
  - $T_{EQUIL} = T_2 + (T_2 – T_1)(T_3 – T_2) / [(T_2 – T_1) – (T_3 - T_2)]$

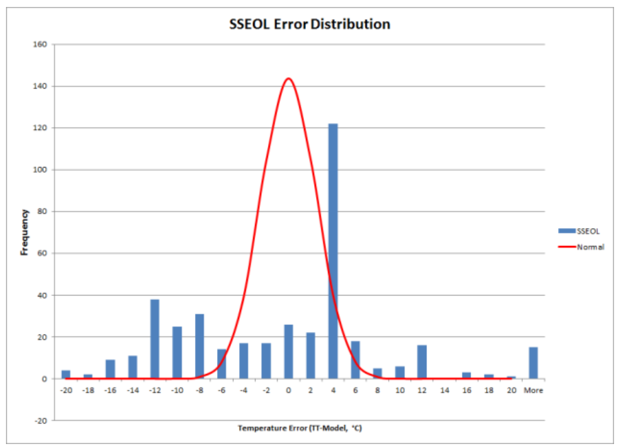
	WSEOL	SSEOL	AEBOL
Qty TCs <+/-10C/hr:	325	346	351
Total TCs Used:	353	353	353
Min:	-768.50	-7.14	-73.58
Avg:	-3.51	5.60	0.07
Max:	22.67	1474.16	69.66
<2C of EQ:	273	312	342
Pct:	77.3%	88.4%	96.9%

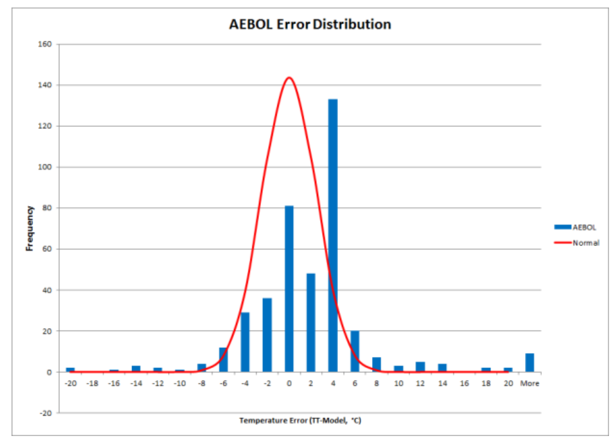
Quick-Look Results

- Assess “error” using test data vs pre-test predictions with no changes to model – uncorrelated results to document starting point:
  - ΔT_{AVG}: -0.6C 0.7C 1.7C
  - $\sigma_{\Delta T}$: 10.8C 12.7C 10.9C
  - ΔT_{MAX}: 90C 89C 100C

Statistic	WSEOL	SSEOL	AEBOL
Qty:	404	404	404
Min Error:	-28.82	-30.01	-29.49
Max Error:	90.13	89.04	100.48
Average Error:	-0.55	-0.65	1.72
Std Dev Error:	10.78	12.74	10.85
Qty > +/-5C error:	41.6%	49.0%	19.8%
Qty > +/-10C error:	22.5%	31.2%	7.7%
Qty > +/-20C error:	4.0%	4.7%	2.7%
Qty within +/-3C error:	41.6%	37.4%	61.9%







WSEOL & SSEOL have large negative error distribution, yet reasonable average error.

Quick-Look: Detailed Assessment

- PY and MY Panels are the primary radiators with the majority of the dissipating units located there.
  - PY Panel runs significantly colder in WSEOL [PY hot case],
  - MY Panel was colder in SSEOL [MY hot case].
  - Since the sinks in each of these hot cases were much warmer than their goals, these colder-than-expected errors in both scenarios implies that dissipations are less than as modelled.

Prop results separate model
SPRU is internal telemetry

WSEOL Error Statistics (TLM - Predicts)

STAT / GROUP	EPP	MYPNL	PYPNL	PROP	BATS	SPRU	BASEPNL	SWS
Min Error	-18.49	-10.32	-28.82		2.04		-8.73	-25.67
Max Error	3.98	42.61	13.88		5.57		6.10	7.28
Average Error	-6.15	1.09	-12.98		2.71		-2.11	-5.77
Std Dev Error	6.29	7.02	7.60		0.45		4.63	8.48
STAT / GROUP	**ANTS**	**ABI**	**GLM**	**SUVI**	**EXIS**	**SEIS**	**MAG**	**TOTAL**
Min Error	-2.80	-19.93	-12.27	4.80	-1.35	-1.73	-8.26	-28.82
Max Error	27.53	14.49	6.70	90.13	3.68	10.50	11.68	90.13
Average Error	6.74	0.45	1.40	19.52	1.33	6.93	-1.54	-0.60
Std Dev Error	9.54	7.09	6.03	26.03	2.67	4.08	5.75	10.87

SSEOL Error Statisitics (TLM - Predicts)

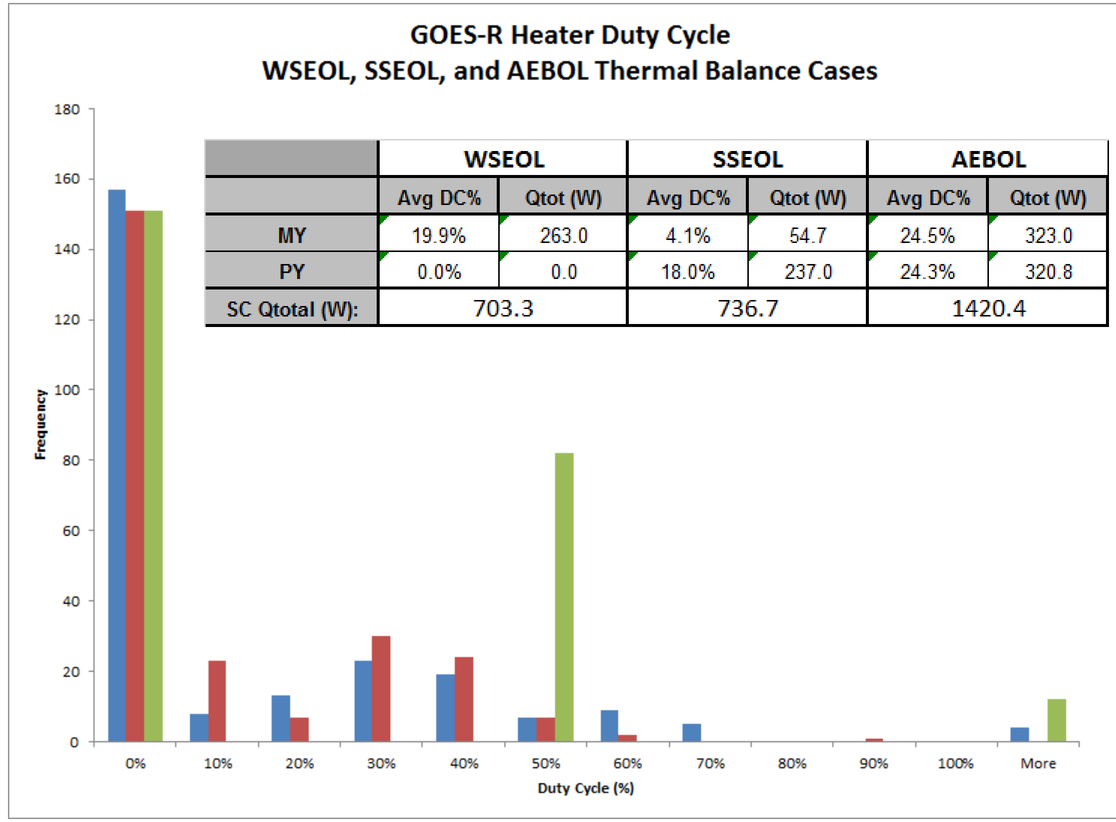
STAT / GROUP	EPP	MYPNL	PYPNL	PROP	BATS	SPRU	BASEPNL	SWS
Min Error	-19.06	-21.14	-17.90		2.23		-10.22	-30.01
Max Error	2.93	22.77	20.92		4.35		11.22	7.47
Average Error	-8.46	-10.08	-4.84		2.85		-2.36	-6.71
Std Dev Error	6.09	6.55	7.03		0.27		6.41	8.88
STAT / GROUP	**ANTS**	**ABI**	**GLM**	**SUVI**	**EXIS**	**SEIS**	**MAG**	**TOTAL**
Min Error	-20.60	-13.95	-12.61	1.92	-1.32	-9.19	3.72	-30.01
Max Error	71.99	14.34	4.19	89.04	3.95	11.73	52.02	89.04
Average Error	19.85	-1.26	-0.32	17.81	1.47	6.45	28.64	-0.58
Std Dev Error	35.07	7.49	5.88	26.34	2.80	7.69	15.48	12.80

AEBOL Error Statisitics (TLM - Predicts)

STAT / GROUP	EPP	MYPNL	PYPNL	PROP	BATS	SPRU	BASEPNL	SWS
Min Error	-14.45	-9.64	-7.65		1.94		-2.06	-29.49
Max Error	2.83	36.97	23.47		6.04		8.91	19.27
Average Error	-2.85	1.48	-0.65		2.74		1.55	-5.96
Std Dev Error	4.91	6.55	5.35		0.52		3.58	10.71
STAT / GROUP	**ANTS**	**ABI**	**GLM**	**SUVI**	**EXIS**	**SEIS**	**MAG**	**TOTAL**
Min Error	-4.40	-6.57	-4.88	-1.19	-1.97	-2.78	-4.53	-29.49
Max Error	100.48	29.61	5.94	86.56	1.37	3.20	27.82	100.48
Average Error	24.62	2.31	1.82	12.17	-0.17	-0.96	3.67	1.75
Std Dev Error	46.15	8.23	3.05	27.17	1.71	1.57	10.38	10.94

Quick-Look Heater Comparison

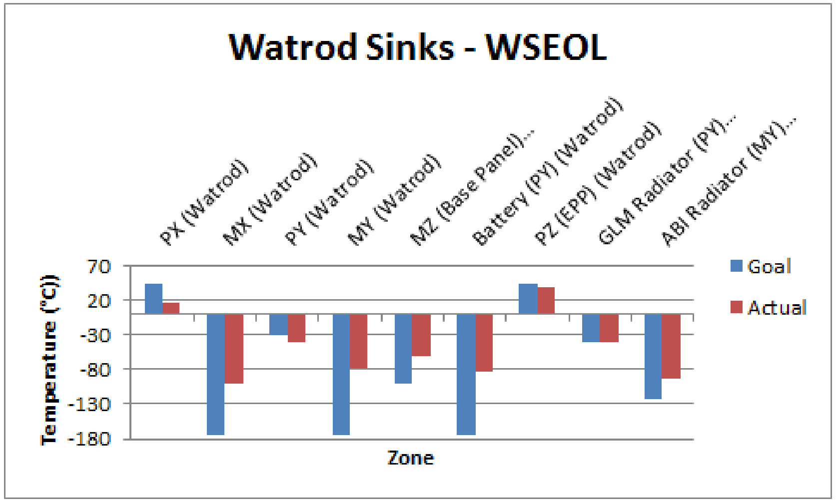
- 277 flight circuits (pri/bu)
  - MY/PY: 22 ea
  - RWAs: 12
  - BATs: 24
  - GLM Radiator: 8
  - ST/SIRU/Isol: 10
  - SPP: 10
  - SEISS: 10
  - Ants/MAG: 10
  - Prop tanks: 10
  - Prop lines/etc: 96

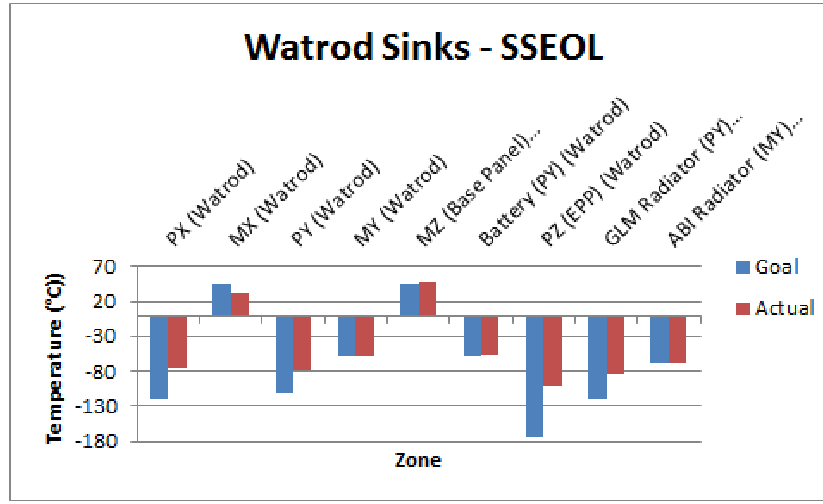


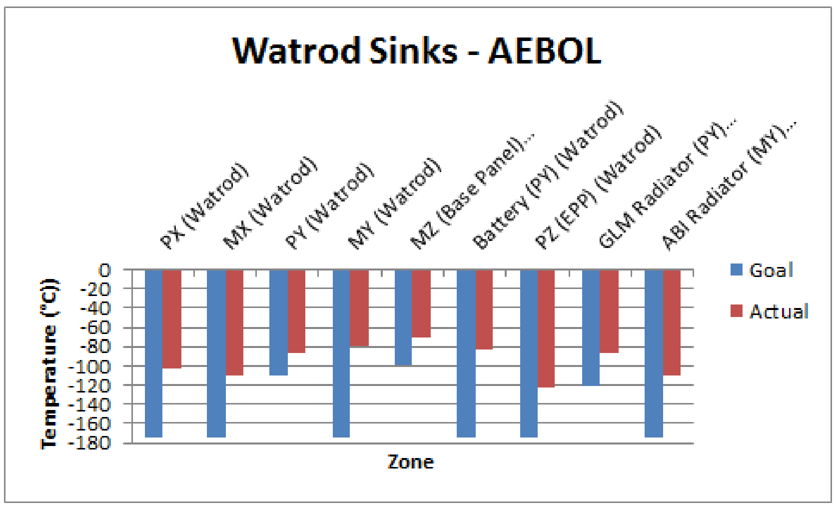
	WSEOL		SSEOL		AEBOL	
	Avg DC%	Qtot (W)	Avg DC%	Qtot (W)	Avg DC%	Qtot (W)
MY	19.9%	263.0	4.1%	54.7	24.5%	323.0
PY	0.0%	0.0	18.0%	237.0	24.3%	320.8
SC Qtotal (W):	703.3		736.7		1420.4	

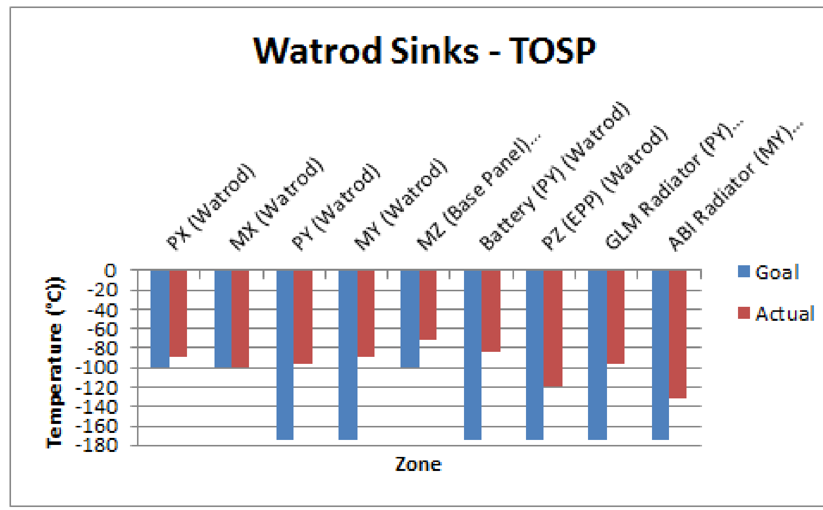
Lower than expected DCs

Quick-Look - Thermal Balance Sinks









Cold watrod sinks were not achieved

RISTM Correlation Process

- Thermal model consists of many parameters –reduce the list of uncertainties and the vast number of things to be tweaked in the correlation.
- The first things that should be checked/updated are the unit dissipations and the target temperatures.
  - Unit dissipations should be based on available current telemetry and/or unit level testing measurements. Ideally this should be done for the pre-test predictions, then updated based on actual SCTV current telemetry and ON/OF state configurations.
  - Sink/target temperatures updated based on test measurements and coupon corrections.

	WSEOL	SSEOL	AEBOL
CDR Qtot:	2895.9	2897.2	2891.3
SCTV Qtot:	2133.2	2137.5	2255.5
dQtot:	-762.7	-759.7	-635.8
dQtot, pct:	-0.3	-0.3	-0.2
PY Panel dQ:	-200.6	-39.6	-197.3
MY Panle dQ:	-344.5	-347.0	-327.1
Miscell dQ:	-217.6	-214.2	-111.5

Correlation Results- Temperature 1

		WSEOL			SSEOL			AEBOL		
TT	Corresponding Node	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)
EPP										
THM_EPP1_TMP	SC_EPP.4022	0.4	2	2	0.1	1	1	-10.4	-9	1
THM_EPP2_TMP	SC_EPP.4042	1.9	2	0	5.5	3	-2	-7.9	-7	1
THM_EPP3_TMP	SC_EPP.4019	9.8	8	-2	1.3	-1	-2	-4.8	-6	-1
THM_EPP4_TMP	SC_EPP.4002	9.6	10	0	-2.3	-1	1	-6.1	-5	2
THM_EPP5_TMP	SC_EPP.5013	2.1	4	2	0.3	0	-1	-8.9	-7	2
THM_EPP6_TMP	SC_EPP.5035	2.3	3	1	3.9	2	-2	-5.4	-4	2
THM_EPP7_TMP	SC_EPP.5034	5.1	4	-1	2.8	2	-1	-3.8	-3	0
THM_EPP8_TMP	SC_EPP.5024	7.4	6	-1	-0.3	-1	0	-6.3	-6	0
THM_EPP9_TMP	SC_EPP.5025	12.4	10	-3	2.2	1	-1	-1.5	-3	-1
THM_STA_SENS1_TMP1	SC_EPP.8031	16.0	15	-1	16.7	15	-1	16.7	16	-1
THM_STA_SENS1_TMP2	SC_EPP.8071	15.8	15	0	16.0	15	-1	16.0	16	0
THM_STA_SENS2_TMP1	SC_EPP.8031	15.6	15	0	15.7	15	0	15.6	16	0
THM_STA_SENS2_TMP2	SC_EPP.8072	16.0	15	-1	16.7	15	-1	16.7	16	-1
THM_STA_SENS3_TMP1	SC_EPP.8031	15.6	15	0	15.7	15	0	15.6	16	0
THM_STA_SENS3_TMP2	SC_EPP.8073	15.6	15	0	15.7	15	0	15.7	16	0
THM_IMU_MOUNT1_TMP	SC_EPP.7513	25.1	25	0	24.7	25	0	24.6	25	0
THM_IMU_MOUNT2_TMP	SC_EPP.7514	24.5	24	0	24.5	24	0	24.3	24	0
THM_IMU_MOUNT3_TMP	SC_EPP.7511	24.0	24	0	23.7	24	0	23.7	24	0
THM_IMU_MOUNT4_TMP	SC_EPP.7512	23.5	23	0	23.6	24	0	23.6	24	0
THM_EP_ISO_1_2_PRI_TMP	SC_NADIR.2	2.2	1	-1	3.8	1	-2	-3.2	-1	3
THM_EP_ISO_1_2_BU_TMP	SC_NADIR.2	1.5	1	0	2.7	1	-1	-3.2	-1	3
THM_EP_ISO_3_4_PRI_TMP	SC_NADIR.18	11.5	9	-2	0.4	0	0	-3.0	-3	0
THM_EP_ISO_3_4_BU_TMP	SC_NADIR.18	11.9	9	-2	0.0	0	0	-3.4	-3	0
THM_EP_ISO_5_6_PRI_TMP	SC_NADIR.32	1.5	4	2	-3.2	-5	-2	-4.9	-5	0
THM_EP_ISO_5_6_BU_TMP	SC_NADIR.38	2.8	6	3	-1.3	0	1	-0.5	-4	-3
THM_ABI_MOUNT1_TMP	SC_EPP.4044	-0.5	1	1	4.9	3	-2	-8.5	-4	4
THM_ABI_MOUNT2_TMP	SC_EPP.4040	7.7	6	-1	2.6	2	0	-2.0	-3	-1
THM_ABI_MOUNT3_TMP	SC_EPP.4030	4.6	4	-1	3.3	2	-1	-7.1	-6	2
THM_GLM_MOUNT1_TMP	SC_EPP.4021	2.1	4	2	-1.0	-2	-1	-9.0	-8	1
THM_GLM_MOUNT2_TMP	SC_EPP.4015	4.6	6	1	-2.5	-4	-2	-8.1	-9	-1
THM_GLM_MOUNT3_TMP	SC_EPP.4012	5.8	5	0	0.8	-1	-2	-6.6	-7	-1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 2

		WSEOL			SSEOL			AEBOL		
TT	Corresponding Node	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)
MY Panel										
THM_MY_PNL01_TMP	SC_MY.21101	3.2	2	-1	0.6	1	0	0.9	1	0
THM_MY_PNL02_TMP	SC_MY.21102	4.5	4	0	1.6	3	1	2.1	3	1
THM_MY_PNL03_TMP	SC_MY.21103	2.1	3	1	2.4	3	1	3.4	4	0
THM_MY_PNL04_TMP	SC_MY.21104	1.0	2	1	1.4	1	0	2.1	2	0
THM_MY_PNL05_TMP	SC_MY.21105	2.0	1	-1	2.2	1	-1	2.6	1	-2
THM_MY_PNL06_TMP	SC_MY.21106	1.5	2	1	1.8	2	1	2.2	2	0
THM_MY_PNL07_TMP	SC_MY.21107	1.7	1	0	1.9	1	-1	2.2	1	-1
THM_MY_PNL08_TMP	SC_MY.21108	0.9	1	0	1.4	0	-1	1.5	1	0
THM_MY_PNL09_TMP	SC_MY.21109	1.1	1	-1	2.1	2	0	1.0	0	-1
THM_MY_PNL10_TMP	SC_MY.21110	1.1	0	-1	2.1	2	0	1.0	0	-1
THM_MY_PNL11_TMP	SC_MY.21111	0.7	1	0	1.7	2	1	0.7	1	0
THM_MY_PNL12_TMP	SC_MY.21112	-1.7	-1	1	-0.7	1	2	-2.2	-1	1
THM_MY_PNL13_TMP	SC_MY.21113	-1.9	-3	-1	-0.8	-1	0	-2.4	-3	-1
THM_MY_PNL14_TMP	SC_MY.21114	-2.7	-4	-1	-1.6	-1	0	-3.4	-4	-1
THM_MY_PNL15_TMP	SC_MY.21115	-2.8	-4	-1	-1.6	-1	0	-3.7	-4	0
THM_MY_PNL16_TMP	SC_MY.21116	-2.0	-2	0	-0.6	0	1	-3.0	-3	1
THM_SEIS_ELECT_TMP	SC_MY.16044	0.4	1	0	1.0	1	0	0.8	1	0
THM_RAW_XB_MOD1_XBM_TMP	SC_MY.25331	1.3	2	1	4.1	3	-1	4.5	3	-1
THM_RAW_XB_MOD1_EPC_TMP	SC_MY.25331	1.0	2	1	3.9	3	-1	4.4	3	-1
THM_RAW_XB_MOD2_XBM_TMP	SC_MY.25332	5.7	4	-2	1.7	3	1	2.2	4	1
THM_RAW_XB_MOD2_EPC_TMP	SC_MY.25332	5.4	4	-2	1.8	3	1	2.4	4	1
THM_SBT1_RX_EPC_TMP	SC_MY.25312	7.1	7	0	7.7	7	0	12.5	11	-2
THM_SBT2_RX_EPC_TMP	SC_MY.25311	11.7	10	-1	12.3	10	-2	7.7	7	-1
THM_SBT1_TX_EPC_TMP	SC_MY.25314	2.7	2	0	3.1	3	-1	7.4	8	0
THM_SBT2_TX_EPC_TMP	SC_MY.25313	6.9	7	0	7.4	6	-1	3.4	3	-1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 3

TT	Corresponding Node	WSEOL TT	WSEOL Model Predict	WSEOL Delta (Model-TT)	SSEOL TT	SSEOL Model Predict	SSEOL Delta (Model-TT)	AEBOL TT	AEBOL Model Predict	AEBOL Delta (Model-TT)
MY Panel										
THM_RIU1_EPC_TMP	SC_MY.25034	5.8	7	1	7.4	9	1	6.8	6	-1
THM_RIU1_S1_TMP	SC_MY.25032	2.2	4	1	3.4	5	2	2.7	3	0
THM_RIU1_S2_TMP	SC_MY.25032	2.7	4	1	3.9	5	1	2.1	3	1
THM_RIU2_EPC_TMP	SC_MY.25033	6.6	7	1	8.1	9	1	7.6	7	-1
THM_RIU2_S1_TMP	SC_MY.25031	2.6	4	1	3.8	5	2	3.0	3	0
THM_RIU2_S2_TMP	SC_MY.25031	3.1	4	1	4.4	5	1	2.4	3	1
THM_RWA1_MTR_TMP	SC_RWA_AS2.5041	7.2	10	3	11.5	12	0	3.3	6	3
THM_RWA1_DVR_TMP	SC_RWA_AS2.2038	8.2	7	-1	9.9	10	0	6.8	7	0
THM_RWA1_BRKT_TMP	SC_RWA_AS2.7605	5.2	8	3	10.0	10	0	1.5	5	3
THM_RWA2_MTR_TMP	SC_RWA_AS1.5241	11.2	11	0	13.6	13	-1	6.7	7	1
THM_RWA2_DVR_TMP	SC_RWA_AS1.2438	8.9	8	-1	10.6	10	-1	7.2	7	0
THM_RWA2_BRKT_TMP	SC_RWA_AS1.9601	9.3	9	0	12.2	11	-1	4.5	6	1
THM_RWA3_MTR_TMP	SC_RWA_AS2.5141	8.8	10	1	12.4	13	0	4.8	7	2
THM_RWA3_DVR_TMP	SC_RWA_AS2.2238	8.2	7	-1	10.1	10	-1	6.9	7	0
THM_RWA3_BRKT_TMP	SC_RWA_AS2.8601	6.8	8	1	11.0	11	0	2.8	5	2
THM_RWA4_MTR_TMP	SC_RWA_AS1.5041	8.5	10	2	12.3	12	0	3.9	7	3
THM_RWA4_DVR_TMP	SC_RWA_AS1.2038	9.3	9	0	11.0	11	0	7.6	8	0
THM_RWA4_BRKT_TMP	SC_RWA_AS1.7602	6.6	9	2	10.9	11	0	2.0	5	3
THM_RWA5_MTR_TMP	SC_RWA_AS2.5241	9.9	10	1	12.4	12	0	6.0	7	1
THM_RWA5_DVR_TMP	SC_RWA_AS2.2438	8.8	6	-3	10.4	8	-2	7.5	5	-2
THM_RWA5_BRKT_TMP	SC_RWA_AS2.9601	7.9	9	1	10.9	10	0	3.9	5	1
THM_RWA6_MTR_TMP	SC_RWA_AS1.5141	9.8	10	0	11.2	11	0	5.6	7	1
THM_RWA6_DVR_TMP	SC_RWA_AS1.2238	9.4	9	-1	10.9	11	0	7.5	8	0
THM_RWA6_BRKT_TMP	SC_RWA_AS1.8601	8.0	8	0	9.5	9	0	3.6	5	1
THM_GPS_RX1_BP_TMP	SC_MY.25002	1.8	3	1	2.0	3	1	2.1	2	0
THM_GPS_RX2_BP_TMP	SC_MY.25001	13.1	13	-1	13.2	12	-1	13.5	12	-2
THM_OBCA_BP_TMP	SC_MY.25301	4.9	5	0	5.2	5	0	3.5	5	1
THM_OBCB_BP_TMP	SC_MY.25301	3.6	5	1	4.0	5	1	5.5	5	-1
THM_OBCA_PS_TMP	SC_MY.25302	3.8	5	1	4.2	5	1	21.6	20	-2
THM_OBCB_PS_TMP	SC_MY.25303	19.5	20	1	20.0	20	0	5.1	5	0
THM_CTPA_PS_TMP	SC_MY.25352	16.2	17	1	16.9	17	0	16.7	17	0
THM_CTPB_PS_TMP	SC_MY.25353	16.9	16	-1	17.5	16	-2	17.4	16	-2
THM_CTPA_BP_TMP	SC_MY.25351	4.7	6	1	5.3	6	0	5.0	5	0
THM_CTPB_BP_TMP	SC_MY.25351	5.1	6	1	5.6	6	0	5.4	5	0

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 4

		WSEOL			SSEOL			AEBOL		
TT	Corresponding Node	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)
MY Panel										
THM_XB_SSPA1_EPC_TMP	SC_MY.25552	1.9	3	1	39.7	39	-1	40.7	39	-1
THM_XB_SSPA1_TMP	SC_MY.25551	2.4	3	0	8.9	8	-1	10.3	8	-2
THM_XB_SSPA2_EPC_TMP	SC_MY.25502	43.6	41	-2	1.6	2	1	2.0	3	0
THM_XB_SSPA2_TMP	SC_MY.25501	10.7	10	-1	1.0	2	1	1.5	3	1
THM_CDAS1_RX_EPC_TMP	SC_MY.25322	5.3	6	1	6.0	6	0	13.2	15	1
THM_CDAS1_TX_EPC_TMP	SC_MY.25324	3.1	3	0	3.6	4	0	15.3	13	-2
THM_CDAS2_RX_EPC_TMP	SC_MY.25321	12.3	15	3	13.1	15	2	5.6	5	0
THM_CDAS2_TX_EPC_TMP	SC_MY.25323	15.0	14	-1	15.5	14	-1	3.6	4	0
THM_GPS_LNA_A_BP_TMP	SC_NADIR.501	10.0	8	-2	0.8	3	2	-1.6	-1	1
THM_GPS_LNA_B_BP_TMP	SC_NADIR.501	10.1	8	-2	1.0	3	2	-1.5	-1	1
THM_SB_DPLXR01_TT1_TMP	SC_MY.25342	1.5	3	1	4.7	2	-2	0.9	2	1
THM_SB_DPLXR02_TT1_TMP	SC_MY.25343	1.9	3	1	2.4	2	0	1.5	2	1
THM_LS_DPLX1_TT1_TMP	SC_MY.25344	1.8	3	1	5.3	3	-2	1.1	2	1
THM_XB_OFA1_TMP	SC_MY.25361	2.0	3	1	6.0	6	0	5.9	6	0
THM_XB_OFA2_TMP	SC_MY.25362	5.7	6	0	2.1	4	2	2.2	4	1
EPS_BCD_CHAN1_TMP	SC_MY.25403	2.1	1	-1	3.1	3	0	2.3	1	-1
EPS_BCD_CHAN2_TMP	SC_MY.25403	1.6	1	0	2.6	3	1	1.6	1	0
EPS_BCD_CHAN3_TMP	SC_MY.25408	2.2	1	-1	3.2	3	0	2.5	1	-1
EPS_BCD_CHAN4_TMP	SC_MY.25408	1.9	1	0	2.9	3	0	2.0	1	-1
EPS_BCD_CHAN5_TMP	SC_MY.25413	2.5	1	-1	3.5	3	0	2.9	1	-2
EPS_BCD_CHAN6_TMP	SC_MY.25413	2.5	1	-1	3.4	3	0	2.6	1	-1
EPS_CDA_TMP	SC_MY.25418	2.3	1	-1	3.3	3	0	2.0	1	-1
EPS_EPDM1_BU_TMP	SC_MY.25422	10.3	10	-1	11.7	11	-1	10.1	10	0
EPS_EPDM1_PRI_TMP	SC_MY.25422	10.7	10	-1	11.9	11	-1	10.4	10	0
EPS_EPDM2_BU_TMP	SC_MY.25423	10.0	11	1	11.4	12	1	10.2	11	1
EPS_EPDM2_PRI_TMP	SC_MY.25423	11.1	11	0	12.3	12	0	11.5	11	0
EPS_EPDM3_BU_TMP	SC_MY.25424	10.8	11	0	12.2	12	0	10.2	10	0
EPS_EPDM3_PRI_TMP	SC_MY.25424	11.3	11	-1	12.6	12	-1	11.0	10	-1
EPS_LCM_A_TMP	SC_MY.25421	2.6	3	0	3.7	5	1	2.6	3	0
EPS_LCM_B_TMP	SC_MY.25421	2.8	3	0	3.8	5	1	2.9	3	0
EPS_LPM_CHAN1_TMP	SC_MY.25419	6.3	5	-2	7.4	6	-1	7.1	5	-2
EPS_LPM_CHAN2_TMP	SC_MY.25419	6.1	5	-1	7.2	6	-1	6.6	5	-2
EPS_LPM_CHAN3_TMP	SC_MY.25420	5.8	5	-1	6.9	6	-1	6.4	5	-2
EPS_LPM_CHAN4_TMP	SC_MY.25420	5.9	5	-1	7.0	6	-1	6.4	5	-2
EPS_SAS_1_4_TMP	SC_MY.25401	4.3	3	-1	5.3	5	0	4.7	3	-2
EPS_SAS_13_16_TMP	SC_MY.25402	5.3	4	-1	6.3	6	-1	5.9	4	-2
EPS_SAS_5_8_TMP	SC_MY.25401	4.4	3	-1	5.4	5	-1	4.9	3	-2
EPS_SAS_9_12_TMP	SC_MY.25402	5.0	4	-1	6.0	6	0	5.5	4	-2
THM_ABI_ELECT1_TMP	SC_MY.16011	3.7	3	-1	0.9	2	1	1.3	2	1
THM_ABI_ELECT2_TMP	SC_MY.16020	4.4	4	0	0.9	3	2	1.3	3	1
THM_ABI_ELECT3_TMP	SC_MY.16012	3.3	5	1	2.5	4	2	3.4	4	1
THM_GLM_ELECT1_TMP	SC_MY.16017	1.7	1	-1	2.2	1	-1	2.4	1	-1
THM_SEIS_DPU_A_TMP	DPU_HOUSING.80101	4.2	4	0	5.2	4	-1	4.3	4	0
THM_SEIS_DPU_B_TMP	DPU_HOUSING.80101	4.2	4	0	5.2	4	-1	4.5	4	0

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 5

TT	Corresponding Node	WSEOL			SSEOL			AEBOL		
		TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)
PY Panel										
THM_PY_PNL01_TMP	SC_PY.21101	4.0	6	2	-2.3	-4	-2	-3.4	-4	0
THM_PY_PNL02_TMP	SC_PY.21102	5.2	7	1	-2.5	-3	-1	-3.4	-3	0
THM_PY_PNL03_TMP	SC_PY.21103	10.8	10	0	-2.4	-3	0	-0.4	0	0
THM_PY_PNL04_TMP	SC_PY.21104	8.4	10	1	-1.6	-1	1	-2.8	-3	0
THM_PY_PNL05_TMP	SC_PY.21105	12.5	10	-2	3.6	1	-3	-0.2	-1	-1
THM_PY_PNL06_TMP	SC_PY.21106	11.2	13	2	-2.2	0	2	-4.0	-3	1
THM_PY_PNL07_TMP	SC_PY.21107	12.0	11	-1	-3.7	-3	1	-4.0	-4	0
THM_PY_PNL08_TMP	SC_PY.21108	15.4	12	-3	2.8	1	-2	-2.4	-3	0
THM_PY_PNL09_TMP	SC_PY.21109	12.3	13	0	-3.8	-1	2	-3.6	-2	2
THM_PY_PNL10_TMP	SC_PY.21110	10.7	13	2	-4.1	-1	3	-4.0	-2	2
THM_PY_PNL11_TMP	SC_PY.21111	11.8	10	-1	-1.5	-3	-1	-2.8	-3	0
THM_PY_PNL12_TMP	SC_PY.21112	8.9	9	0	-4.1	-4	0	-5.2	-4	1
THM_PY_PNL13_TMP	SC_PY.21113	6.2	8	2	-6.6	-5	1	-8.7	-6	3
THM_PY_PNL14_TMP	SC_PY.21114	9.7	10	0	-5.3	-4	2	-3.0	-4	-1
THM_PY_PNL15_TMP	SC_PY.21115	4.7	8	3	-8.9	-6	3	-10.1	-6	4
THM_PY_PNL16_TMP	SC_PY.21116	4.9	1	-4	-8.6	-14	-5	-13.9	-15	-1
THM_EPCU_CONVA_BP_TMP	SC_PY.28015	5.2	8	3	-8.3	-6	3	-9.9	-6	4
THM_EPCU_CONVB_BP_TMP	SC_PY.28016	5.2	8	3	-8.2	-6	3	-9.9	-6	4
THM_EPCU_CONVC_BP_TMP	SC_PY.28017	5.2	8	3	-8.1	-6	3	-9.8	-6	4
THM_RIU3_EPC_TMP	SC_PY.28003	14.8	14	-1	3.6	2	-1	1.4	1	0
THM_RIU3_S1_TMP	SC_PY.28001	11.1	11	0	-0.5	-1	0	-2.6	-2	1
THM_RIU3_S2_TMP	SC_PY.28001	12.7	11	-1	1.6	-1	-2	-2.2	-2	1
THM_RIU4_EPC_TMP	SC_PY.28004	14.9	16	1	1.8	3	2	1.4	3	1
THM_RIU4_S1_TMP	SC_PY.28002	11.2	12	1	-2.3	-1	2	-2.1	-1	1
THM_RIU4_S2_TMP	SC_PY.28002	11.4	12	0	-1.5	-1	1	-3.6	-1	2
THM_SB_RX1_1_TMP	SC_PY.26001	9.7	11	2	1.9	1	0	0.7	1	0
THM_SB_RX1_2_TMP	SC_PY.26002	9.8	11	1	13.6	13	-1	11.6	12	1
THM_SB_RX2_1_TMP	SC_PY.26051	13.8	14	0	-4.1	-2	3	-4.8	-2	3
THM_SB_RX2_2_TMP	SC_PY.26052	26.0	25	-1	-3.9	-2	2	-4.7	-2	3
THM_UHF_RX1_1_TMP	SC_PY.27002	19.9	18	-2	-2.3	-3	-1	3.5	4	1
THM_UHF_RX1_2_TMP	SC_PY.27003	32.4	31	-1	-2.3	-3	-1	15.3	18	2
THM_UHF_RX2_1_TMP	SC_PY.27052	9.4	10	1	2.4	5	2	-4.9	-4	1
THM_UHF_RX2_2_TMP	SC_PY.27053	9.7	10	0	15.4	15	-1	-4.9	-4	1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 6

		WSEOL			SSEOL			AEBOL		
TT	Corresponding Node	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)
PY Panel										
THM_LTWT1_LDALC_IBP_TMP	SC_PY.25231	13.4	12	-2	-3.6	-2	1	0.9	2	1
THM_LTWT2_LDALC_IBP_TMP	SC_PY.25232	10.3	9	-1	4.0	2	-2	0.4	1	1
THM_LTWT3_LDALC_IBP_TMP	SC_PY.25234	3.9	7	3	1.2	1	0	1.1	1	0
THM_LTWT4_LDALC_IBP_TMP	SC_PY.25235	14.7	14	-1	-5.0	-2	3	-2.2	0	2
THM_LTWTS1_LDALC_IBP_TMP	SC_PY.25233	14.6	14	0	3.5	3	0	-4.1	-3	1
THM_LTWTS2_LDALC_IBP_TMP	SC_PY.25236	12.3	12	0	-1.6	1	3	-6.6	-3	4
THM_LTWTS1_HVEPC_IBP_TMP	SC_PY.25223	24.4	23	-1	13.8	13	0	-1.8	0	1
THM_LTWTS2_HVEPC_IBP_TMP	SC_PY.25226	21.3	18	-3	4.4	7	3	-5.3	-1	4
THM_LTWT1_HVEPC_IBP_TMP	SC_PY.25221	23.0	21	-2	-2.5	0	2	8.8	11	2
THM_LTWT2_HVEPC_IBP_TMP	SC_PY.25222	12.1	12	0	14.6	13	-2	10.0	11	1
THM_LTWT3_HVEPC_IBP_TMP	SC_PY.25224	5.7	9	4	4.1	3	-1	3.1	3	0
THM_LTWT4_HVEPC_IBP_TMP	SC_PY.25225	21.2	19	-3	-4.0	-1	3	2.6	5	2
THM_LTWT1_TWT_XBP_TMP	SC_PY.25516	33.4	31	-2	-2.4	-2	0	16.8	21	4
THM_LTWT2_TWT_XBP_TMP	SC_PY.25536	14.5	10	-4	32.8	31	-2	29.6	30	0
THM_LTWT3_TWT_XBP_TMP	SC_PY.25576	2.9	7	4	6.8	7	0	8.6	7	-2
THM_LTWT4_TWT_XBP_TMP	SC_PY.25636	27.4	25	-3	-4.1	-1	3	7.0	11	4
THM_LTWTS1_TWT_XBP_TMP	SC_PY.25556	38.3	36	-3	25.4	25	0	-2.8	-3	0
THM_LTWTS2_TWT_XBP_TMP	SC_PY.25616	33.1	31	-2	14.9	20	5	-5.3	-3	3
THM_DUAL_XB_RX1_EPC_TMP	SC_PY.25301	8.0	10	2	0.9	3	2	-0.5	1	1
THM_DUAL_XB_RX2_EPC_TMP	SC_PY.25302	11.9	12	0	-3.5	-2	2	-4.4	-2	3
THM_REF_OSC1_BOX_TMP	SC_PY.25011	11.4	11	-1	1.2	0	-1	-1.3	0	1
THM_REF_OSC2_BOX_TMP	SC_PY.25012	13.1	13	0	0.2	-2	-2	-1.7	-3	-1
THM_REF_OSC3_BOX_TMP	SC_PY.25013	13.0	13	0	1.2	0	-1	-2.9	-1	2
THM_HP_ISO_01_LD_TMP	SC_PY.25241	16.6	16	-1	-2.3	-1	1	3.3	5	2
THM_HP_ISO_02_LD_TMP	SC_PY.25242	13.7	12	-2	4.7	10	5	2.5	7	5
THM_HP_ISO_03_LD_TMP	SC_PY.25244	2.8	7	4	-3.1	-1	2	-4.2	-1	4
THM_HP_ISO_04_LD_TMP	SC_PY.25245	12.3	13	1	-4.4	-1	3	-3.7	-1	3
THM_HP_ISO_S1_LD_TMP	SC_PY.25243	17.2	15	-2	4.3	5	0	-3.0	-3	0
THM_HP_ISO_S2_LD_TMP	SC_PY.25246	11.8	14	2	-2.4	1	3	-5.5	-3	3
THM_LB_OFA6_TMP	SC_PY.25261	17.6	17	0	3.6	4	0	4.0	6	2
THM_LB_OFA7_TMP	SC_PY.25262	18.2	17	-2	4.3	8	3	4.6	6	2
THM_UHF_OFA8_TMP	SC_PY.25122	11.7	11	-1	0.2	-2	-2	-2.9	-3	0
THM_LB_OMUX01_TT1_TMP	SC_PY.25251	4.1	6	2	-3.1	-4	-1	-4.5	-4	0
THM_LB_OMUX01_TT2_TMP	SC_PY.25251	4.3	6	2	-2.9	-4	-1	-4.2	-4	0
THM_LB_OMUX02_TT1_TMP	SC_PY.25252	6.0	7	1	-1.1	-3	-2	-2.4	-3	-1
THM_LB_OMUX02_TT2_TMP	SC_PY.25252	6.1	7	1	-1.0	-3	-2	-2.4	-3	-1
THM_UHF_DPLXR01_TT1_TMP	SC_PY.25106	12.3	11	-1	1.4	-1	-2	-2.7	-2	0
THM_MAG_IB_ELCT_BP_TMP	SC_PY.25001	12.9	11	-2	-2.8	0	2	-4.9	-2	3
THM_MAG_OB_ELCT_BP_TMP	SC_PY.25002	16.7	14	-2	3.1	6	3	1.6	3	1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 7

TT	Corresponding Node	WSEOL TT	WSEOL Model Predict	WSEOL Delta (Model-TT)	SSEOL TT	SSEOL Model Predict	SSEOL Delta (Model-TT)	AEBOL TT	AEBOL Model Predict	AEBOL Delta (Model-TT)
Batteries										
THM_BAT1_CELL01_TMP	SC_BATT1.1	15.3	16	0	15.3	16	0	15.2	16	0
THM_BAT1_CELL02_TMP	SC_BATT1.2	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT1_CELL03_TMP	SC_BATT1.3	15.4	16	0	15.5	16	0	15.4	16	0
THM_BAT1_CELL04_TMP	SC_BATT1.4	15.3	16	0	15.2	16	0	15.2	16	0
THM_BAT1_CELL05_TMP	SC_BATT1.5	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT1_CELL06_TMP	SC_BATT1.6	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT1_CELL07_TMP	SC_BATT1.7	15.2	16	0	15.3	16	0	15.1	16	1
THM_BAT1_CELL08_TMP	SC_BATT1.8	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT1_CELL09_TMP	SC_BATT1.9	15.3	16	0	15.4	16	0	15.2	16	0
THM_BAT1_CELL10_TMP	SC_BATT1.10	15.2	16	0	15.3	16	0	15.1	16	0
THM_BAT1_CELL11_TMP	SC_BATT1.11	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT1_CELL12_TMP	SC_BATT1.12	15.4	15	0	15.5	16	0	15.3	16	0
THM_BAT1_CELL13_TMP	SC_BATT1.13	15.1	16	1	15.2	16	1	15.1	16	1
THM_BAT1_CELL14_TMP	SC_BATT1.14	15.4	16	1	15.4	16	0	15.4	16	1
THM_BAT1_CELL15_TMP	SC_BATT1.15	15.2	16	1	15.3	16	1	15.1	16	1
THM_BAT1_CELL16_TMP	SC_BATT1.16	15.1	16	0	15.2	16	0	15.0	16	0
THM_BAT1_CELL17_TMP	SC_BATT1.17	15.3	16	0	15.3	16	0	15.2	16	0
THM_BAT1_CELL18_TMP	SC_BATT1.18	15.0	16	0	15.2	16	0	14.9	16	1
THM_BAT1_CELL19_TMP	SC_BATT1.19	15.2	16	0	15.3	16	0	15.1	16	0
THM_BAT1_CELL20_TMP	SC_BATT1.20	15.7	16	0	15.6	16	0	15.7	16	0
THM_BAT1_CELL21_TMP	SC_BATT1.21	15.6	16	0	15.6	16	0	15.5	16	0
THM_BAT1_CELL22_TMP	SC_BATT1.22	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT1_CELL23_TMP	SC_BATT1.23	15.9	16	0	15.7	16	0	16.0	16	0
THM_BAT1_CELL24_TMP	SC_BATT1.24	16.0	16	0	15.8	16	0	16.0	16	0
THM_BAT1_CELL25_TMP	SC_BATT1.25	15.0	16	0	15.2	16	0	15.0	16	1
THM_BAT1_CELL26_TMP	SC_BATT1.26	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT1_CELL27_TMP	SC_BATT1.27	15.5	16	0	15.5	16	0	15.4	16	0
THM_BAT1_CELL28_TMP	SC_BATT1.28	15.0	16	1	15.1	16	0	14.9	16	1
THM_BAT1_CELL29_TMP	SC_BATT1.29	15.4	16	0	15.4	16	0	15.4	16	0
THM_BAT1_CELL30_TMP	SC_BATT1.30	15.4	16	0	15.4	16	0	15.3	16	0
THM_BAT1_CELL31_TMP	SC_BATT1.31	15.0	16	1	15.2	16	0	14.9	16	1
THM_BAT1_CELL32_TMP	SC_BATT1.32	15.2	16	0	15.2	16	0	15.2	16	1
THM_BAT1_CELL33_TMP	SC_BATT1.33	15.4	16	0	15.4	16	0	15.4	16	0
THM_BAT1_CELL34_TMP	SC_BATT1.34	14.8	16	1	15.0	16	0	14.7	16	1
THM_BAT1_CELL35_TMP	SC_BATT1.35	15.1	16	1	15.1	16	0	15.0	16	1
THM_BAT1_CELL36_TMP	SC_BATT1.36	15.1	16	0	15.2	16	0	14.9	16	1
THM_BAT1_BANK01_TMP	SC_BATT1.2	15.6	16	0	15.6	16	0	15.6	16	0
THM_BAT1_BANK02_TMP	SC_BATT1.5	15.8	16	0	15.6	16	0	15.8	16	0
THM_BAT1_BANK03_TMP	SC_BATT1.8	15.6	16	0	15.6	16	0	15.6	16	0
THM_BAT1_BANK04_TMP	SC_BATT1.11	15.7	16	0	15.7	16	0	15.7	16	0
THM_BAT1_BANK05_TMP	SC_BATT1.14	15.6	16	1	15.6	16	0	15.6	16	0
THM_BAT1_BANK06_TMP	SC_BATT1.17	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT1_BANK07_TMP	SC_BATT1.20	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT1_BANK08_TMP	SC_BATT1.23	16.1	16	0	15.8	16	0	16.1	16	0
THM_BAT1_BANK09_TMP	SC_BATT1.26	15.6	16	0	15.5	16	0	15.5	16	0
THM_BAT1_BANK10_TMP	SC_BATT1.29	15.5	16	0	15.4	16	0	15.4	16	0
THM_BAT1_BANK11_TMP	SC_BATT1.32	15.5	16	0	15.5	16	0	15.6	16	0
THM_BAT1_BANK12_TMP	SC_BATT1.35	15.3	16	0	15.3	16	0	15.3	16	0
THM_BAT1_OSR_TMP	SC_BATT1.207	13.0	12	-1	13.5	13	-1	12.9	12	-1
THM_BAT1_AUX3_SPRU_TMP	SC_BATT1.11	15.6	16	0	15.6	16	0	15.6	16	0
THM_BAT1_AUX4_SPRU_TMP	SC_BATT1.29	14.9	16	1	15.1	16	1	14.8	16	1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 8

TT	Corresponding Node	WSEOL TT	WSEOL Model Predict	WSEOL Delta (Model-TT)	SSEOL TT	SSEOL Model Predict	SSEOL Delta (Model-TT)	AEBOL TT	AEBOL Model Predict	AEBOL Delta (Model-TT)
Batteries										
THM_BAT2_CELL01_TMP	SC_BATT2.1	15.3	16	0	15.3	16	0	15.3	16	0
THM_BAT2_CELL02_TMP	SC_BATT2.2	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT2_CELL03_TMP	SC_BATT2.3	15.3	16	0	15.4	16	0	15.2	16	0
THM_BAT2_CELL04_TMP	SC_BATT2.4	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT2_CELL05_TMP	SC_BATT2.5	15.9	16	0	15.7	16	0	16.0	16	0
THM_BAT2_CELL06_TMP	SC_BATT2.6	15.8	16	0	15.7	16	0	15.8	16	0
THM_BAT2_CELL07_TMP	SC_BATT2.7	15.2	16	1	15.3	16	0	15.1	16	1
THM_BAT2_CELL08_TMP	SC_BATT2.8	15.4	16	0	15.4	16	0	15.4	16	0
THM_BAT2_CELL09_TMP	SC_BATT2.9	15.3	16	0	15.4	16	0	15.2	16	1
THM_BAT2_CELL10_TMP	SC_BATT2.10	15.1	16	0	15.2	16	0	15.0	16	1
THM_BAT2_CELL11_TMP	SC_BATT2.11	15.3	16	0	15.3	16	0	15.3	16	0
THM_BAT2_CELL12_TMP	SC_BATT2.12	15.1	15	0	15.3	16	0	15.0	16	1
THM_BAT2_CELL13_TMP	SC_BATT2.13	15.2	16	1	15.3	16	1	15.1	16	1
THM_BAT2_CELL14_TMP	SC_BATT2.14	15.5	16	1	15.5	16	1	15.4	16	1
THM_BAT2_CELL15_TMP	SC_BATT2.15	15.4	16	1	15.5	16	0	15.2	16	1
THM_BAT2_CELL16_TMP	SC_BATT2.16	15.3	16	0	15.4	16	0	15.2	16	0
THM_BAT2_CELL17_TMP	SC_BATT2.17	15.3	16	0	15.4	16	0	15.2	16	0
THM_BAT2_CELL18_TMP	SC_BATT2.18	15.2	16	0	15.5	15	0	15.0	16	1
THM_BAT2_CELL19_TMP	SC_BATT2.19	15.2	16	0	15.4	16	0	15.1	15	0
THM_BAT2_CELL20_TMP	SC_BATT2.20	15.7	16	0	15.6	16	0	15.7	16	0
THM_BAT2_CELL21_TMP	SC_BATT2.21	15.7	16	0	15.6	16	0	15.6	16	0
THM_BAT2_CELL22_TMP	SC_BATT2.22	15.4	16	0	15.5	16	0	15.5	16	0
THM_BAT2_CELL23_TMP	SC_BATT2.23	15.9	16	0	15.7	16	0	16.0	16	0
THM_BAT2_CELL24_TMP	SC_BATT2.24	15.9	16	0	15.7	16	0	15.9	16	0
THM_BAT2_CELL25_TMP	SC_BATT2.25	15.0	16	1	15.2	15	0	15.0	15	1
THM_BAT2_CELL26_TMP	SC_BATT2.26	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT2_CELL27_TMP	SC_BATT2.27	15.5	16	0	15.6	16	0	15.5	16	0
THM_BAT2_CELL28_TMP	SC_BATT2.28	15.1	16	1	15.4	16	0	15.1	16	1
THM_BAT2_CELL29_TMP	SC_BATT2.29	15.4	16	0	15.5	16	0	15.4	16	0
THM_BAT2_CELL30_TMP	SC_BATT2.30	15.5	16	0	15.5	16	0	15.4	16	0
THM_BAT2_CELL31_TMP	SC_BATT2.31	15.1	16	0	15.4	16	0	15.1	16	0
THM_BAT2_CELL32_TMP	SC_BATT2.32	15.5	16	0	15.6	16	0	15.6	16	0
THM_BAT2_CELL33_TMP	SC_BATT2.33	15.5	16	0	15.6	16	0	15.5	16	0
THM_BAT2_CELL34_TMP	SC_BATT2.34	14.9	16	1	15.2	16	0	14.8	16	1
THM_BAT2_CELL35_TMP	SC_BATT2.35	15.2	16	1	15.3	16	0	15.2	16	1
THM_BAT2_CELL36_TMP	SC_BATT2.36	15.2	16	0	15.3	16	0	15.1	16	0
THM_BAT2_BANK01_TMP	SC_BATT2.2	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT2_BANK02_TMP	SC_BATT2.5	16.0	16	0	15.8	16	0	16.1	16	0
THM_BAT2_BANK03_TMP	SC_BATT2.8	15.6	16	0	15.5	16	0	15.5	16	0
THM_BAT2_BANK04_TMP	SC_BATT2.11	15.5	16	0	15.5	16	0	15.4	16	0
THM_BAT2_BANK05_TMP	SC_BATT2.14	15.6	16	1	15.6	16	0	15.5	16	1
THM_BAT2_BANK06_TMP	SC_BATT2.17	15.6	16	0	15.6	16	0	15.5	16	0
THM_BAT2_BANK07_TMP	SC_BATT2.20	15.6	16	0	15.5	16	0	15.6	16	0
THM_BAT2_BANK08_TMP	SC_BATT2.23	15.9	16	0	15.6	16	0	16.0	16	0
THM_BAT2_BANK09_TMP	SC_BATT2.26	15.5	16	0	15.5	16	0	15.6	16	0
THM_BAT2_BANK10_TMP	SC_BATT2.29	15.4	16	1	15.4	16	0	15.4	16	0
THM_BAT2_BANK11_TMP	SC_BATT2.32	15.5	16	0	15.5	16	0	15.5	16	0
THM_BAT2_BANK12_TMP	SC_BATT2.35	15.3	16	0	15.4	16	0	15.3	16	0
THM_BAT2_OSR_TMP	SC_BATT2.207	13.2	11	-2	13.8	12	-2	13.0	11	-2
THM_BAT2_AUX3_SPRU_TMP	SC_BATT2.11	15.4	16	0	15.4	16	0	15.4	16	0
THM_BAT2_AUX4_SPRU_TMP	SC_BATT2.29	15.5	16	0	15.5	16	0	15.5	16	0

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 9

		WSEOL			SSEOL			AEBOL		
TT	Corresponding Node	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)	TT	Model Predict	Delta (Model-TT)
Core Structure										
THM_BASEPNL_PX_TMP	SC_CORE.1582	10.5	9	-1	15.0	12	-3	1.5	4	3
THM_BASEPNL_MX_TMP	SC_CORE.1672	6.3	6	-1	10.0	8	-2	-2.0	-1	1
THM_BLKHD_MY_TMP	SC_CORE.1309	4.7	7	3	5.7	8	3	3.4	4	1
THM_BLKHD_PY_TMP	SC_CORE.1259	12.9	10	-3	2.3	3	1	-1.7	-1	1
THM_INTRC_PX_TMP	SC_CORE.1029	10.2	10	0	2.6	9	6	-0.5	4	4
THM_INTRC_MY_TMP	SC_CORE.674	7.8	8	0	8.9	8	-1	3.0	3	0
THM_INTRC_PY_TMP	SC_CORE.874	9.2	10	1	4.3	5	0	-2.3	0	2
THM_INTRC_MX_TMP	SC_CORE.1182	7.5	9	1	7.6	9	2	0.5	1	1
THM_TRANS1_TMP	SC_CORE.2102	9.6	7	-2	5.5	10	4	-2.7	0	3
THM_TRANS2_TMP	SC_CORE.2103	10.2	8	-3	9.8	11	1	-2.0	2	4
SPP										
THM_SPP1_TMP	SC_SWS.991	2.0	1	-1	2.0	1	-1	2.8	1	-1
THM_SPP2_TMP	SC_SWS.993	5.0	2	-3	4.9	2	-3	5.8	2	-4
THM_SPP3_TMP	SC_SWS.992	4.3	3	-1	3.9	3	-1	2.5	3	1
THM_SPP4_TMP	SC_SWS.994	6.2	3	-3	5.3	3	-3	1.3	0	-1
THM_SPP5_TMP	SC_SWS.998	10.6	8	-2	9.3	8	-1	5.2	6	1
THM_SPP6_TMP	SC_SWS.990	7.5	7	0	6.4	7	1	2.1	6	3
THM_SPP7_TMP	SC_SWS.997	8.0	8	0	6.7	7	1	3.0	6	3
THM_SPP8_TMP	SC_SWS.996	10.6	5	-5	9.0	5	-4	5.6	3	-3
THM_SPP9_TMP	SC_SWS.999	5.3	2	-3	3.6	2	-1	3.6	1	-2
THM_SPP10_TMP	SC_SWS.995	2.6	0	-2	1.2	1	-1	1.9	1	0
THM_FSSD_TMP	SC_SWS.1005	4.7	3	-2	4.1	3	-1	0.6	0	-1
THM_SADE2_1_TMP	SC_SWS.5020	0.0	2	2	-0.7	-3	-2	-16.9	-14	2
THM_SADE2_2_TMP	SC_SWS.5074	3.4	3	-1	2.6	-3	-6	-11.8	-14	-2
THM_SA_ROOT_HINGE1_TMP	SC_ROOTHINGE.56088	2.7	1	-2	-13.2	-14	-1	-13.2	-14	0
THM_SA_ROOT_HINGE2_TMP	SC_ROOTHINGE.56081	2.6	0	-2	-12.3	-14	-2	-13.0	-14	-1
THM_SIU_S1_TMP	SC_SWS.1001	5.2	3	-2	4.5	2	-2	1.7	0	-1
THM_SIU_S2_TMP	SC_SWS.1001	5.2	3	-2	4.6	2	-2	0.6	0	0
THM_SIU_EPC_TMP	SC_SWS.1101	7.1	4	-3	6.5	4	-2	4.0	2	-2
THM_SADA1_TMP	SC_SADA.26	8.7	10	1	-7.4	-4	4	-9.4	-5	5
THM_SADA2_TMP	SC_SADA.31	8.7	10	1	-7.5	-4	4	-9.4	-5	5
THM_SEGA1_TMP	SC_SEGA.7003	2.0	6	4	1.4	6	5	-5.1	5	11
THM_SEGA2_TMP	SC_SEGA.7011	2.8	6	3	2.1	6	4	-4.4	5	10
THM_SPP_TB1_TMP	SC_TRLBRNG.7012	6.7	2	-5	4.0	1	-3	-5.2	-3	2
THM_SPP_TB2_TMP	SC_TRLBRNG.7003	3.9	3	-1	1.6	2	0	-7.1	-3	5
Antenna										
THM_OMNI_FWD_TMP	SC_OMNI.111	-0.3	-1	-1	-31.7	-9	22	-81.7	-66	16
THM_OMNI_AFT_TMP	SC_OMNI.311	-20.2	-22	-2	32.5	29	-4	-28.5	-29	0
THM_XB_GMBL_RO_TMP	SC_ANTXBAND.15805	24.4	26	2	5.8	7	1	4.6	7	2
THM_XB_GMBL_DPLY_TMP	SC_ANTXBAND.15901	29.8	26	-3	1.2	1	0	1.3	1	-1
THM_GPS_ANT_1_TMP	SC_ANTGPS.1	26.5	25	-2	-27.4	-26	2	-27.5	-26	2
THM_GPS_ANT_2_TMP	SC_ANTGPS.1	26.4	25	-2	-27.5	-26	2	-27.5	-26	2
THM_SAR_ANT1_TMP	SC_ANTSAR.1	-27.6	-28	0	24.5	26	1	-27.1	-28	0
THM_SAR_ANT2_TMP	SC_ANTSAR.1	-26.7	-28	-1	25.1	26	1	-26.3	-28	-1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation Results- Temperature 10

TT	Corresponding Node	WSEOL TT	WSEOL Model Predict	WSEOL Delta (Model-TT)	SSEOL TT	SSEOL Model Predict	SSEOL Delta (Model-TT)	AEBOL TT	AEBOL Model Predict	AEBOL Delta (Model-TT)
GLM Radiator										
THM_GLM_RAD1_TMP	SC_GLM.18011	-4.7	-6	-1	-5.2	-6	-1	-5.4	-6	-1
THM_GLM_RAD2_TMP	SC_GLM.18013	-5.8	-8	-2	-5.5	-8	-2	-5.1	-8	-3
THM_GLM_RAD3_TMP	SC_GLM.18012	-8.7	-9	0	-8.6	-9	0	-8.7	-9	0
THM_GLM_RAD4_TMP	SC_GLM.18015	-8.4	-8	0	-8.6	-9	0	-8.9	-9	0
THM_GLM_RAD5_TMP	SC_GLM.18014	-7.3	-8	0	-7.8	-8	0	-7.3	-8	0
THM_GLM_RAD6_TMP	SC_GLM.18016	-4.9	-5	-1	-5.2	-5	0	-5.1	-5	0
SEISS										
THM_SEIS_HPIPE01_TMP	SC_SEISS.12511	-7.6	-5	2	-5.3	-7	-1	-15.8	-16	0
THM_SEIS_HPIPE02_TMP	SC_SEISS.12512	-7.4	-5	2	-5.1	-7	-1	-15.7	-16	0
THM_SEIS_HPIPE03_TMP	SC_SEISS.12513	-6.8	-7	0	-8.9	-7	1	-17.3	-17	0
THM_SEIS_HPIPE04_TMP	SC_SEISS.12514	-7.4	-7	0	-7.3	-7	0	-17.4	-17	0
THM_SEIS_HPIPE05_TMP	SC_SEISS.12515	-6.8	-7	0	-7.2	-7	0	-17.1	-17	0
THM_SEIS_HPIPE06_TMP	SC_SEISS.12516	-6.7	-6	0	-7.0	-7	0	-17.1	-17	0
THM_SEIS_HPIPE07_TMP	SC_SEISS.12517	-7.5	-6	1	-6.8	-7	-1	-17.4	-17	1
THM_SEIS_HPIPE08_TMP	SC_SEISS.12518	-6.6	-6	0	-6.7	-7	-1	-16.9	-17	0
THM_SEIS_SGPS_PX_A_TMP	SGPS_PX_HOUSING.81671	-17.2	-17	0	-3.0	1	4	-17.6	-17	0
THM_SEIS_SGPS_PX_B_TMP	SGPS_PX_HOUSING.81671	-17.3	-17	0	-3.1	1	4	-17.6	-17	1
THM_SEIS_SGPS_PX_PRI_TMP	SC_SEISS.12519	-17.6	-17	0	-5.6	1	7	-17.6	-17	0
Mag										
THM_MAG_IB_SENS_X_TMP	MAG1BOBX.7	16.6	19	2	50.1	47	-3	16.3	18	2
THM_MAG_IB_SENS_Y_TMP	MAG1BOBY.1	18.2	18	0	50.3	47	-3	17.9	18	0
THM_MAG_IB_SENS_Z_TMP	MAG1BOBZ.7	19.9	20	0	50.2	47	-3	19.9	20	0
THM_MAG_OB_SENS_X_TMP	MAG2BOBX.7	14.6	14	-1	53.4	50	-4	14.3	13	-1
THM_MAG_OB_SENS_Y_TMP	MAG2BOBY.1	17.1	14	-3	53.5	50	-4	16.9	14	-3
THM_MAG_OB_SENS_Z_TMP	MAG2BOBZ.7	19.8	20	0	53.1	50	-3	19.8	20	0
THM_MAG_BOOM_PRI_TMP	MAG_CAN.8	-6.5	-6	0	46.3	46	0	-6.4	-7	0
THM_MAG_BOOM_BU_TMP	MAG_CAN.6	-5.7	-5	1	45.1	46	1	-6.7	-6	1

RED = >3° C >TLM

BLUE = >+3° C < TLM

Correlation – Heater Power 1

		Heater		WSEOL			SSEOL			AEBOL		
		HCR #	GOES-R Descriptor	TVAC Duty Cycle (%)	Duty Cycle (%)	DC% Delta (Model - Telem)	TVAC Duty Cycle (%)	Duty Cycle (%)	DC% Delta (Model - Telem)	TVAC Duty Cycle (%)	Duty Cycle (%)	DC% Delta (Model - Telem)
MY	Panel	1	MY Panel HTR 01A	24.9	27	2	6.2	6	0	35.7	35	-1
		2	MY Panel HTR 01B	24.9	27	2	6.2	6	0	35.7	35	-1
		3	MY Panel HTR 02A	24.9	27	2	6.2	6	0	35.7	35	-1
		4	MY Panel HTR 02B	24.9	27	2	6.2	6	0	35.7	35	-1
		5	MY Panel HTR 03A	24.9	27	2	6.2	6	0	35.7	35	-1
		6	MY Panel HTR 03B	24.9	27	2	6.2	6	0	35.7	35	-1
		7	MY Panel HTR 04A	24.9	27	2	6.2	6	0	35.7	35	-1
		8	MY Panel HTR 04B	24.9	27	2	6.2	6	0	35.7	35	-1
		9	MY Panel HTR 05A	24.9	27	2	6.2	6	0	35.7	35	-1
		10	MY Panel HTR 05B	24.9	27	2	6.2	6	0	35.7	35	-1
		11	MY Panel HTR 06A	24.9	27	2	6.2	6	0	35.7	35	-1
		12	MY Panel HTR 06B	24.9	27	2	6.2	6	0	35.7	35	-1
		13	MY Panel HTR 07A	24.9	27	2	6.2	6	0	35.7	35	-1
		14	MY Panel HTR 07B	24.9	27	2	6.2	6	0	35.7	35	-1
		15	MY Panel HTR 08A	0.0	0	0	0.0	0	0	0.0	0	0
		16	MY Panel HTR 08B	0.0	0	0	0.0	0	0	0.0	0	0
		17	MY Panel HTR 09A	0.0	0	0	0.0	0	0	0.0	0	0
		18	MY Panel HTR 09B	0.0	0	0	0.0	0	0	0.0	0	0
		19	MY Panel HTR 10A	0.0	0	0	0.0	0	0	0.0	0	0
		20	MY Panel HTR 10B	0.0	0	0	0.0	0	0	0.0	0	0
		21	MY Panel HTR 11A	0.0	0	0	0.0	0	0	0.0	0	0
		22	MY Panel HTR 11B	0.0	0	0	0.0	0	0	0.0	0	0
		279	RWA 1 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		281	RWA 2 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		283	RWA 3 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		285	RWA 4 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		287	RWA 5 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		289	RWA 6 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
PY	Panel	47	PY Panel HTR 01A	0.0	0	0	22.2	22	0	26.1	29	3
		48	PY Panel HTR 01B	0.0	0	0	22.2	22	0	26.1	29	3
		49	PY Panel HTR 02A	0.0	0	0	22.2	22	0	26.1	29	3
		50	PY Panel HTR 02B	0.0	0	0	22.2	22	0	26.1	29	3
		51	PY Panel HTR 03A	0.0	0	0	22.2	22	0	26.1	29	3
		52	PY Panel HTR 03B	0.0	0	0	22.2	22	0	26.1	29	3
		53	PY Panel HTR 04A	0.0	0	0	22.2	22	0	26.1	29	3
		54	PY Panel HTR 04B	0.0	0	0	22.2	22	0	26.1	29	3
		55	PY Panel HTR 05A	0.0	0	0	22.2	22	0	26.1	29	3
		56	PY Panel HTR 05B	0.0	0	0	22.2	22	0	26.1	29	3
		57	PY Panel HTR 06A	0.0	0	0	22.2	22	0	26.1	29	3
		58	PY Panel HTR 06B	0.0	0	0	22.2	22	0	26.1	29	3
		59	PY Panel HTR 07A	0.0	0	0	22.2	22	0	26.1	29	3
		60	PY Panel HTR 07B	0.0	0	0	22.2	22	0	26.1	29	3
		61	PY Panel HTR 08A	0.0	0	0	22.2	22	0	26.1	29	3
		62	PY Panel HTR 08B	0.0	0	0	22.2	22	0	26.1	29	3
		63	PY Panel HTR 09A	0.0	0	0	22.2	22	0	26.1	29	3
		64	PY Panel HTR 09B	0.0	0	0	0.0	0	0	18.7	22	3
		65	PY Panel HTR 10A	0.0	0	0	0.0	0	0	18.7	22	3
		66	PY Panel HTR 10B	0.0	0	0	0.0	0	0	18.7	22	3
		67	PY Panel HTR 11A	0.0	0	0	0.0	0	0	18.7	22	3
		68	PY Panel HTR 11B	0.0	0	0	0.0	0	0	18.7	22	3

RED = DC >3% >TLM

BLUE =DC >+3% < TLM

Correlation – Heater Power 2

		Heater		WSEOL			SSEOL			AEBOL		
		HCR #	GOES-R Descriptor	TVAC Duty Cycle (%)	Duty Cycle (%)	DC% Delta (Model - Telem)	TVAC Duty Cycle (%)	Duty Cycle (%)	DC% Delta (Model - Telem)	TVAC Duty Cycle (%)	Duty Cycle (%)	DC% Delta (Model - Telem)
MY		24	BAT1_1 PRI HTR	63.2	61	-2	51.6	48	-4	71.6	63	-9
		26	BAT1_2 PRI HTR	52.7	54	1	48.9	43	-6	62.6	56	-7
		28	BAT1_3 PRI HTR	53.6	58	4	52.5	47	-5	62.6	61	-2
		30	BAT1_4 PRI HTR	64.1	66	2	48.0	49	1	73.0	69	-4
		32	BAT1_5 PRI HTR	55.1	48	-7	35.6	38	2	59.7	48	-12
		34	BAT1_6 PRI HTR	43.7	53	9	45.7	42	-4	61.7	54	-8
		36	BAT2_1 PRI HTR	61.5	63	2	43.1	48	5	68.9	66	-3
		38	BAT2_2 PRI HTR	51.6	53	1	44.8	42	-3	57.9	55	-3
		40	BAT2_3 PRI HTR	56.0	56	0	43.6	45	1	58.8	59	0
		42	BAT2_4 PRI HTR	60.8	61	0	35.6	49	13	62.2	63	1
		44	BAT2_5 PRI HTR	40.1	41	1	31.1	32	1	44.8	43	-2
		46	BAT2_6 PRI HTR	50.9	45	-6	32.4	36	4	43.1	46	3
			Battery 1 Average	55.4	57	2	47.1	44	-3	65.2	58	-7
			Battery 2 Average	53.5	57	4	38.4	44	6	55.9	59	3
Earth Pointing	Platform (EPP)	69	GLM Radiator Assembly 1 A HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		70	GLM Radiator Assembly 1 B HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		71	GLM Radiator Assembly 2 A HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		72	GLM Radiator Assembly 2 B HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		73	GLM Radiator Assembly 3 A HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		74	GLM Radiator Assembly 3 B HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		75	GLM Radiator Assembly 4 A HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		76	GLM Radiator Assembly 4 B HTR	13.4	8	-5	35.6	35	-1	43.7	41	-3
		81	STA SENSOR PRI HTR	9.8	13	3	82.2	80	-2	89.3	90	1
		83	IMU (SSIRU) Coldplate 1 HTR	29.2	32	3	51.6	54	2	68.8	69	0
		84	IMU (SSIRU) Coldplate 2 HTR	0.0	0	0	0.0	0	0	0.0	0	0
		85	IMU (SSIRU) Coldplate 3 HTR	0.0	0	0	0.0	0	0	0.0	0	0
	Panel	86	Isolator_1_and_2_PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		88	Isolator_3_and_4_PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		90	Isolator_5_and_6_PRI HTR	0.0	0	0	0.0	0	0	37.3	61	24
Solar Wing Subsystem (SWS)		93	SADA PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		95	SADE2 PRI HTR	0.0	0	0	0.0	0	0	33.9	0	-34
		97	SEGA PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		99	TRAILER BEARING PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		101	ROOT_HINGE PRI HTR	0.0	0	0	21.3	9	-12	22.6	19	-4
		102	Sun Pointing Platform 1 (SPP) PRI HTR	44.5	50	5	46.2	52	6	71.6	71	-1
		104	Sun Pointing Platform 2 (SPP) PRI HTR	0.0	0	0	0.0	0	0	0.0	3	3
		106	Sun Pointing Platform 3 (SPP) PRI HTR	0.0	0	0	0.0	5	5	40.1	32	-8
		108	Sun Pointing Platform 4 (SPP) PRI HTR	0.0	0	0	0.0	0	0	0.0	3	3
SEISS		110	SEISS Support Structure 1 PRI HTR	0.0	0	0	0.0	0	0	0.0	0	0
		111	SEISS Support Structure 1 BU HTR	0.0		0	0.0		0	0.0		0
		112	SEISS Support Structure 2 PRI HTR	0.0	52	52	0.0	10	10	0.0	19	19
		113	SEISS Support Structure 2 BU HTR	100.0		-100	0.0		0	43.0		-43
		114	SEISS Support Structure 3 PRI HTR	0.0	52	52	0.0	10	10	0.0	19	19
		115	SEISS Support Structure 3 BU HTR	21.2		-21	29.3		-29	15.5		-15
		116	SEISS Support Structure 4 PRI HTR	0.0	52	52	0.0	10	10	0.0	19	19
		117	SEISS Support Structure 4 BU HTR	100.0		-100	23.1		-23	45.7		-46
		118	SGPS PX PRI HTR	3.9	1	-3	0.0	0	0	18.7	8	-11
Antenna		120	X-Band Gimbal PRI HTR	0.0	0	0	34.7	24	-11	36.8	26	-11
	Antenna	124	GPS Antenna PRI HTR	0.0	0	0	42.7	25	-18	45.3	29	-16
		126	SAR Antenna PRI HTR	21.4	12	-9	0.0	0	0	31.5	19	-12
Mag	Boom	128	Magnetometer Boom PRI HTR	25.8	28	2	0.0	0	0	31.5	34	3
		129	Magnetometer Boom BU HTR	25.8	28	2	0.0	0	0	31.5	34	3
		130	Magnetometer 1 IB HTR (ACHE)	49.1	52	3	0.0	0	0	57.3	56	-1
		131	Magnetometer 2 OB HTR (ACHE)	63.4	61	-2	0.0	0	0	64.3	64	0

Large DC error due to not modelling reflux heat pipe operation.

RED = DC >3% >TLM

BLUE =DC >+3% < TLM

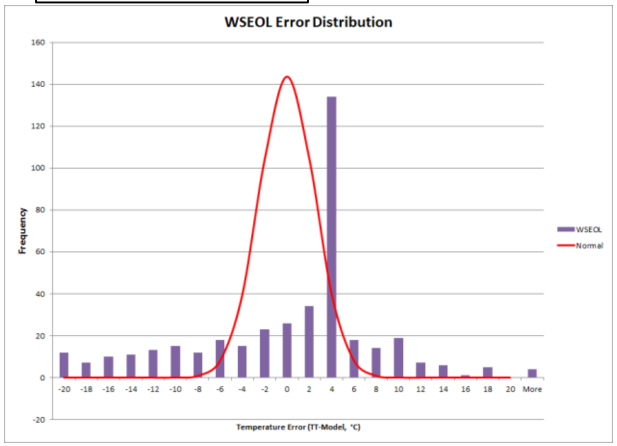
RISTM Correlation: Summary

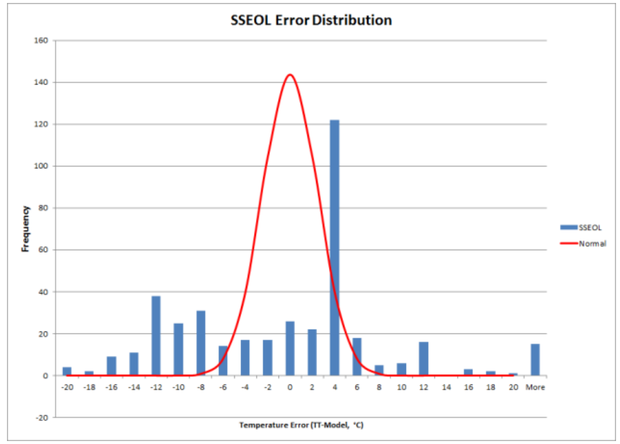
- Over 500 changes were made to the RISTM during the ~6 month correlation period.
- By far, the two biggest contributors to the correlation:
  - Updated (and corrected sinks)
  - Updated dissipations using SC telemetry (I, V) and unit test data
- Panel-panel and box-panel Kij changes were numerous as well….
- Most of the changes were to correct, tweak, adjust panel-panel or box-panel conductors, and adjust local MLI estar or adjust MLI coverage.
- Refinements to model mostly includes nodalization (model granularity) in specific areas.
- Final correlation errors > 5° C were included in final mission predicts as "lingering" error.

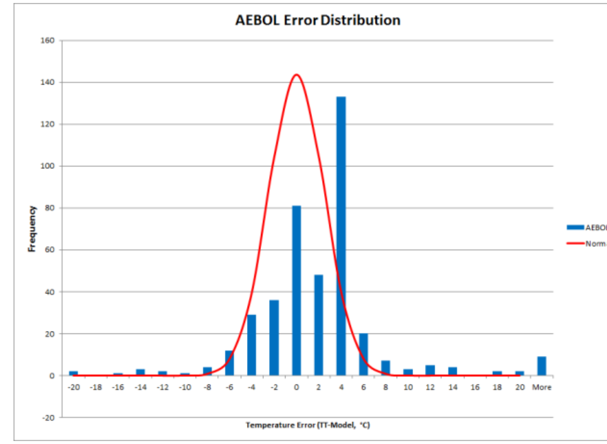
Category	Qty
Total	515
SCTV Sink:	17
Disspations:	48
Conductances:	233
Heaters:	28
MLI:	15
ESTAR:	50
Emittance:	22
Model Refinements:	36
Model Errors:	32
Miescellaneous:	34

Correlation: Beginning to End

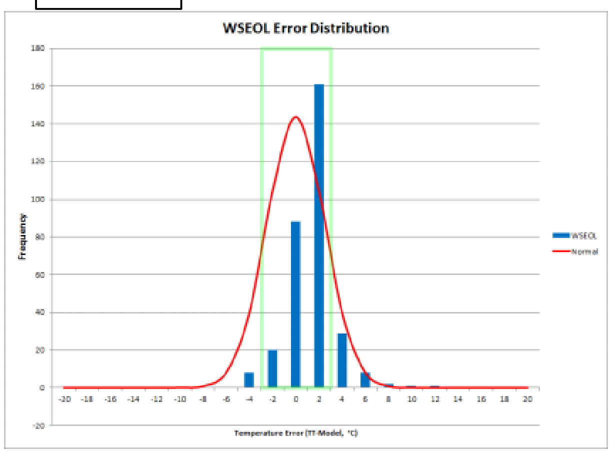
Quick-Look:

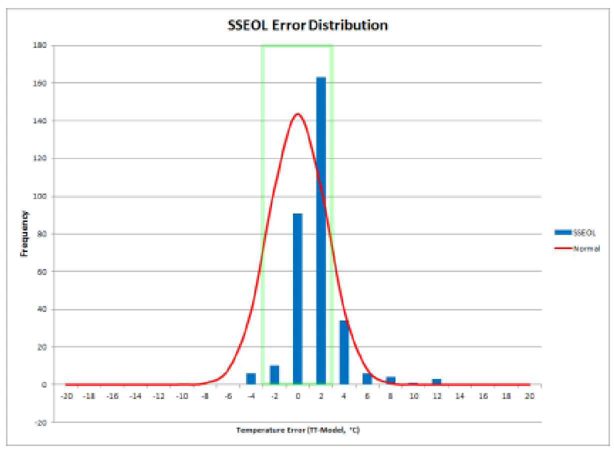


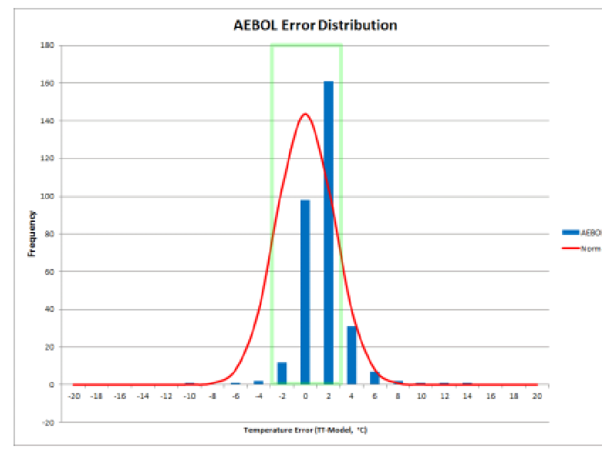




Final:







Most "errors" fall within the idealized Gaussian distribution; very few outliers.

Propulsion Model (PSTM) Correlation

- Since essentially everything is heater controlled, most temperatures were “the same” between the model and the telemetry.
  - Lock on heaters with heater duty cycles recorded in TVAC to ensure proper energy balance throughout the spacecraft.
  - Correlate core/structure and MY/PY panel TTs in RISTM- set as sinks for PSTM to ensure the interior of the S/C is properly bounded and sees the correct environment.
  - Correlate thruster TTs to properly bound the end of each prop line.
  - Ensure control TT (minimum of group) in each prop line zone matches TVAC control TT.
  - Correlate all remaining TTs.
  - Unlock all heaters and let them control to on-station set points.
  - Correlate all heaters to heater duty cycles recorded in TVAC.

TTs

Red	= > 10°C	(predict too warm)
Light orange	= 3°C – 10°C	(predict too warm)
Light blue	= -3°C – -10°C	(predict too cold)
Blue	= < -10°C	(predict too cold)

Heaters

Red	= > 10%	(predict too high)
Light orange	= 3% – 10%	(predict too high)
Light blue	= -3% – -10%	(predict too low)
Blue	= < -10%	(predict too low)

Propulsion Model – PSTM

Table 5: Final TT Results

			WSEOL			SSEOL			AEBOL		
	TT Mnemonic	Corresponding Node	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)
	THM_AJ13_GG_TMP	ARCJET_04.9914	-44.5	-45	0	37.5	27	-11	-46.6	-49	-2
	THM_AJ13_VLV1_TMP	ARCJET_04.9916	19.6	19	-1	28.1	27	-1	19.5	19	0
	THM_AJ13_VLV2_TMP	ARCJET_04.9916	20.0	19	-1	28.1	27	-1	20.0	19	-1
	THM_AJ14_GG_TMP	ARCJET_03.9914	-42.5	-44	-1	35.9	26	-10	-44.5	-48	-4
	THM_AJ14_VLV1_TMP	ARCJET_03.9916	20.3	19	-1	27.7	26	-1	20.3	19	-1
	THM_AJ14_VLV2_TMP	ARCJET_03.9916	19.5	19	0	27.5	26	-1	19.5	19	0
	THM_AJ15_GG_TMP	ARCJET_01.9914	32.1	24	-8	-48.5	-45	3	-50.3	-50	0
	THM_AJ15_VLV1_TMP	ARCJET_01.9916	21.7	25	4	19.1	19	0	19.4	19	0
	THM_AJ15_VLV2_TMP	ARCJET_01.9916	21.7	25	4	20.0	19	-1	20.3	19	-1
	THM_AJ16_GG_TMP	ARCJET_02.9914	32.1	25	-8	-46.7	-45	1	-49.3	-50	0
	THM_AJ16_VLV1_TMP	ARCJET_02.9916	21.2	25	4	19.7	19	-1	19.3	19	0
	THM_AJ16_VLV2_TMP	ARCJET_02.9916	21.3	25	4	21.5	19	-2	21.1	19	-2
	THM_LAE_HYDRA_VLV_TMP	MAIN.2151	16.4	16	-1	16.5	16	-1	21.4	-4	-25
	THM_LAE_OX_VLV_TMP	MAIN.2151	16.1	16	0	16.2	16	0	22.1	-4	-26
	THM_LAE_SHELF1_TMP	MAIN.10012	3.9	12	8	7.4	13	6	3.7	-2	-5
	THM_LAE_SHELF2_TMP	MAIN.10055	4.9	12	7	8.2	13	5	8.0	-1	-9
	THM_LAE_SHELF3_TMP	MAIN.10032	4.1	12	8	8.0	13	5	6.7	-1	-8
	THM_LAE_SHELF4_TMP	MAIN.10007	4.5	12	8	8.6	14	5	5.2	-1	-7
PX Base Line	THM_RCS_LIN_BASEPX1_TMP	MAIN.654050	19.5	20	0	19.8	20	0	19.3	19	0
	THM_RCS_LIN_BASEPX2_TMP	MAIN.654152	21.8	30	8	35.1	26	-9	33.9	37	3
	THM_RCS_LIN_BASEPX3_TMP	MAIN.754004	40.8	36	-5	37.0	32	-5	53.4	45	-8
	THM_RCS_LIN_BASEPX4_TMP	MAIN.754324	37.5	33	-4	27.8	26	-2	43.3	39	-5
	THM_RCS_LIN_BASEPX5_TMP	MAIN.754084	41.6	37	-4	28.2	32	4	40.6	43	2
PYPX Line	THM_RCS_LIN_PYPX6_TMP	MAIN.753021	21.5	19	-2	19.7	19	0	19.7	20	0
	THM_RCS_LIN_PYPX7_TMP	MAIN.753015	19.7	20	0	21.5	22	0	21.5	23	1
MYPX Line	THM_RCS_LIN_MYPX8_TMP	MAIN.752044	22.5	19	-3	19.7	19	0	19.7	19	0
	THM_RCS_LIN_MYPX9_TMP	MAIN.752135	19.9	23	3	22.6	26	4	20.7	26	5
PYMX Line	THM_RCS_LIN_PYMX10_TMP	MAIN.753052	19.8	20	0	22.1	20	-3	19.8	19	0
	THM_RCS_LIN_PYMX11_TMP	MAIN.753043	22.6	23	0	20.0	24	4	20.6	25	4

PSTM Correlation – Temperatures 1

			WSEOL			SSEOL			AEBOL		
	TT Mnemonic	Corresponding Node	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)
LAE Trans Flow Line	THM_RCS_LIN_PREISO12_TMP	MAIN.750101	25.6	29	3	39.3	32	-8	33.1	29	-4
	THM_RCS_LIN_PREISO19_TMP	MAIN.750019	20.0	19	-1	19.8	19	0	19.8	19	0
	THM_RCS_LIN_LAEX14_TMP	MAIN.756222	25.5	25	0	36.2	26	-10	30.0	24	-6
LAE Flow Line	THM_RCS_LIN_LAE13_TMP	MAIN.650067	19.8	19	0	19.7	19	0	20.4	20	-1
	THM_RCS_LIN_LAE15_TMP	MAIN.756184	22.2	25	3	29.1	28	-1	23.8	27	3
	THM_RCS_LIN_LAE16_TMP	MAIN.756240	27.2	28	0	35.5	32	-4	31.1	29	-2
	THM_RCS_LIN_LAE17_TMP	MAIN.754199	21.0	27	6	33.2	30	-3	21.3	27	6
	THM_RCS_LIN_LAE18_TMP	MAIN.754328	22.6	23	0	32.5	25	-7	19.6	22	2
MX Base Line	THM_RCS_LIN_BASEMX20_TMP	MAIN.655060	19.5	19	0	19.8	19	0	19.3	20	0
	THM_RCS_LIN_BASEMX21_TMP	MAIN.755088	36.5	32	-5	35.3	30	-6	44.7	37	-8
	THM_RCS_LIN_BASEMX22_TMP	MAIN.755097	39.3	34	-6	28.6	28	0	34.5	35	1
	THM_RCS_LIN_BASEMX23_TMP	MAIN.755145	42.5	34	-8	33.8	30	-4	49.3	41	-9
Pressure Line	THM_RCS_LIN_PRESS24_TMP	MAIN.751187	31.6	34	2	32.2	33	1	34.3	35	1
	THM_RCS_LIN_PRESS25_TMP	MAIN.751183	39.1	39	0	37.3	38	0	43.0	41	-2
	THM_RCS_LIN_PRESS26_TMP	MAIN.651210	30.3	30	0	30.3	30	0	30.3	30	0
PX VPR Line	THM_RCS_LIN_PXV27_TMP	MAIN.756007	30.7	30	0	30.6	30	0	30.6	30	0
	THM_RCS_LIN_PXV28_TMP	MAIN.756078	35.2	36	0	38.6	38	-1	37.7	37	0
MX VPR Line	THM_RCS_LIN_MXV29_TMP	MAIN.757392	30.3	30	0	30.3	30	0	20.9	21	0
	THM_RCS_LIN_MXV30_TMP	MAIN.757295	60.4	51	-9	53.7	47	-7	48.1	39	-9
	THM_RCS_LIN_MXV31_TMP	MAIN.757212	44.0	39	-5	44.6	38	-7	37.7	33	-5
	THM_RCS_LIN_MXV32_TMP	MAIN.757003	68.2	60	-8	58.8	55	-4	54.8	44	-11
PX LIQ Line	THM_RCS_LIN_PXL33_TMP	MAIN.656036	19.8	19	0	19.6	20	0	19.5	20	0
	THM_RCS_LIN_PXL34_TMP	MAIN.756281	34.1	44	10	50.8	50	-1	48.1	55	7
	THM_RCS_LIN_PXL35_TMP	MAIN.756250	33.9	40	6	47.8	45	-3	46.6	50	3
	THM_RCS_LIN_PXL36_TMP	MAIN.756064	28.2	33	5	31.3	34	3	31.7	38	7
	THM_RCS_LIN_PXL37_TMP	MAIN.756115	24.1	31	7	26.5	33	6	26.9	37	10
MX LIQ Line	THM_RCS_LIN_MXL38_TMP	MAIN.757388	25.5	25	-1	22.8	22	0	24.6	25	0
	THM_RCS_LIN_MXL39_TMP	MAIN.757097	32.9	29	-4	19.9	24	4	25.3	31	6
	THM_RCS_LIN_MXL40_TMP	MAIN.757273	19.7	20	0	21.2	19	-2	19.7	19	0
	THM_RCS_LIN_MXL41_TMP	MAIN.757054	31.4	30	-1	22.5	26	3	29.5	33	3
	THM_RCS_LIN_MXL42_TMP	MAIN.757276	24.3	26	2	20.2	24	4	25.3	28	3
	THM_RCS_LIN_MYMX43_TMP	MAIN.752056	22.9	19	-3	19.9	19	0	22.2	19	-3

PSTM Correlation – Temperatures 2

			WSEOL			SSEOL			AEBOL		
	TT Mnemonic	Corresponding Node	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)
MYMX Line	THM_RCS_LIN_MYMX44_TMP	MAIN.752088	19.9	21	1	20.4	21	1	19.9	21	1
	THM_REA05_VLV1_TMP	REA_02.9902	16.2	16	0	16.6	16	-1	16.3	16	0
	THM_REA05_VLV2_TMP	REA_02.9901	18.8	20	1	16.1	17	0	19.1	21	2
	THM_REA06_VLV1_TMP	REA_01.9902	16.3	16	0	17.1	16	-1	16.1	16	0
	THM_REA06_VLV2_TMP	REA_01.9901	17.2	19	2	16.1	16	0	17.2	20	3
	THM_REA07_VLV1_TMP	REA_04.9902	16.6	16	-1	29.8	18	-12	16.5	16	-1
	THM_REA07_VLV2_TMP	REA_04.9901	18.6	19	0	28.7	18	-11	18.7	19	1
	THM_REA08_VLV1_TMP	REA_03.9902	16.3	16	0	29.5	18	-12	16.3	16	0
	THM_REA08_VLV2_TMP	REA_03.9901	18.2	19	0	28.6	18	-11	18.3	19	1
	THM_REA09_VLV1_TMP	REA_06.9902	16.1	16	0	17.2	16	-1	16.1	16	0
	THM_REA09_VLV2_TMP	REA_06.9901	18.5	18	0	16.4	16	0	19.0	20	1
	THM_REA10_VLV1_TMP	REA_05.9902	16.1	16	0	15.9	16	0	16.0	16	0
	THM_REA10_VLV2_TMP	REA_05.9901	17.8	18	1	15.2	16	1	18.0	20	2
	THM_REA11_VLV1_TMP	REA_08.9902	16.5	16	-1	16.5	16	-1	16.2	16	0
	THM_REA11_VLV2_TMP	REA_08.9901	17.9	19	1	16.3	17	0	18.0	21	3
	THM_REA12_VLV1_TMP	REA_07.9902	16.4	16	0	16.1	16	0	16.1	16	0
	THM_REA12_VLV2_TMP	REA_07.9901	18.5	19	0	16.3	17	0	18.7	21	2
	THM_HBT02_SHELF1_TMP	HBT_01.1	16.1	16	0	18.6	25	7	-7.9	-1	7
	THM_HBT02_SHELF2_TMP	HBT_01.1	19.3	16	-3	18.6	25	7	-6.8	-1	6
	THM_HBT02_VLV1_TMP	HBT_01.9908	51.6	40	-11	24.6	27	2	16.2	16	-1
	THM_HBT02_VLV2_TMP	HBT_01.9907	52.0	40	-12	24.7	27	2	16.8	15	-2
	THM_HBT03_SHELF1_TMP	HBT_02.1	16.0	16	0	26.9	27	0	-9.2	-1	9
	THM_HBT03_SHELF2_TMP	HBT_02.1	21.2	16	-5	25.0	27	2	-6.8	-1	6
	THM_HBT03_VLV1_TMP	HBT_02.9908	55.3	41	-14	23.0	28	5	16.4	16	-1
	THM_HBT03_VLV2_TMP	HBT_02.9907	55.5	40	-15	22.7	28	5	17.5	15	-2
	THM_LTR17_CATBED_TMP	LTR_07.9912	-27.1	-26	1	30.9	21	-9	-29.6	-30	0
	THM_LTR17_VLV1_TMP	LTR_07.9902	16.9	17	0	16.2	17	1	16.8	17	0
	THM_LTR17_VLV2_TMP	LTR_07.9902	16.9	17	0	16.2	17	1	16.8	17	0
	THM_LTR18_CATBED_TMP	LTR_08.9912	-25.4	-25	0	32.4	21	-11	-29.7	-30	0

PSTM Correlation – Temperatures 3

TT Mnemonic	Corresponding Node	WSEOL TT	WSEOL Predict (°C)	WSEOL Delta (°C)	SSEOL TT	SSEOL Predict (°C)	SSEOL Delta (°C)	AEBOL TT	AEBOL Predict (°C)	AEBOL Delta (°C)
THM_LTR18_VLV1_TMP	LTR_08.9902	16.5	17	1	16.0	17	1	16.5	17	0
THM_LTR18_VLV2_TMP	LTR_08.9902	16.8	17	0	16.0	17	1	16.8	17	0
THM_LTR19_CATBED_TMP	LTR_05.512	30.3	21	-9	-32.2	-33	-1	-34.5	-36	-2
THM_LTR19_VLV1_TMP	LTR_05.502	17.6	17	0	16.5	17	1	16.5	17	1
THM_LTR19_VLV2_TMP	LTR_05.502	17.6	17	0	16.7	17	1	16.7	17	0
THM_LTR20_CATBED_TMP	LTR_06.612	30.3	21	-9	-29.9	-27	2	-32.2	-30	2
THM_LTR20_VLV1_TMP	LTR_06.602	17.7	17	0	16.5	17	1	16.7	17	0
THM_LTR20_VLV2_TMP	LTR_06.602	17.7	17	0	16.9	17	0	17.1	17	0
THM_LTR21_CATBED_TMP	LTR_02.212	30.1	21	-9	-31.0	-32	-1	-34.4	-36	-2
THM_LTR21_VLV1_TMP	LTR_02.202	16.4	17	1	16.6	17	1	16.5	17	1
THM_LTR21_VLV2_TMP	LTR_02.202	16.4	17	1	16.6	17	1	16.5	17	1
THM_LTR22_CATBED_TMP	LTR_01.112	30.3	20	-10	-29.7	-29	0	-32.2	-34	-2
THM_LTR22_VLV1_TMP	LTR_01.102	15.8	17	1	16.6	17	1	16.6	17	0
THM_LTR22_VLV2_TMP	LTR_01.102	15.9	17	1	16.6	17	1	16.6	17	0
THM_LTR23_CATBED_TMP	LTR_04.412	-29.7	-28	2	32.6	22	-11	-31.5	-31	1
THM_LTR23_VLV1_TMP	LTR_04.402	16.6	17	1	17.2	17	0	16.6	17	0
THM_LTR23_VLV2_TMP	LTR_04.402	16.7	17	1	17.3	17	0	16.7	17	0
THM_LTR24_CATBED_TMP	LTR_03.312	-29.7	-28	2	32.6	21	-11	-29.8	-31	-1
THM_LTR24_VLV1_TMP	LTR_03.302	16.8	17	0	17.8	17	0	16.9	17	0
THM_LTR24_VLV2_TMP	LTR_03.302	16.9	17	0	17.7	17	0	17.0	17	0
THM_LTR25_CATBED_TMP	LTR_09.9912	30.0	18	-12	-27.3	-19	9	-32.2	-30	2
THM_LTR25_VLV1_TMP	LTR_09.9902	16.7	17	1	17.0	17	0	16.7	17	0
THM_LTR25_VLV2_TMP	LTR_09.9902	16.7	17	1	17.3	17	0	17.0	17	0
THM_LTR26_CATBED_TMP	LTR_11.9912	27.5	23	-5	-29.7	-31	-1	-32.0	-34	-2
THM_LTR26_VLV1_TMP	LTR_11.9902	16.2	17	1	16.7	17	1	16.5	17	0
THM_LTR26_VLV2_TMP	LTR_11.9902	16.2	17	1	17.0	17	0	16.8	17	0
THM_LTR27_CATBED_TMP	LTR_12.9912	28.1	23	-5	-33.7	-33	1	-34.7	-36	-1
THM_LTR27_VLV1_TMP	LTR_12.9902	17.0	17	0	16.4	17	1	16.4	17	1
THM_LTR27_VLV2_TMP	LTR_12.9902	17.0	17	0	16.8	17	0	16.9	17	0
THM_LTR28_CATBED_TMP	LTR_10.9912	30.0	18	-12	-34.8	-19	15	-37.2	-30	8

PSTM Correlation – Temperatures 4

TT Mnemonic	Corresponding Node	WSEOL			SSEOL			AEBOL		
		TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)	TT	Predict (°C)	Delta (°C)
THM_LTR28_VLV1_TMP	LTR_10.9902	17.0	17	0	16.2	17	1	16.4	17	1
THM_LTR28_VLV2_TMP	LTR_10.9902	17.1	17	0	17.3	17	0	17.6	17	-1
THM_LTR29_CATBED_TMP	LTR_16.9912	-29.6	-28	1	30.1	23	-7	-29.7	-32	-2
THM_LTR29_VLV1_TMP	LTR_16.9902	16.6	17	1	16.5	17	1	16.6	17	1
THM_LTR29_VLV2_TMP	LTR_16.9902	17.3	17	0	16.5	17	1	17.3	17	0
THM_LTR30_CATBED_TMP	LTR_14.9912	-29.8	-31	-1	30.0	22	-8	-32.2	-34	-2
THM_LTR30_VLV1_TMP	LTR_14.9902	16.7	17	1	16.7	17	1	16.6	17	1
THM_LTR30_VLV2_TMP	LTR_14.9902	16.8	17	0	16.7	17	1	16.7	17	0
THM_LTR31_CATBED_TMP	LTR_13.9912	-34.7	-34	0	31.1	22	-9	-37.1	-40	-2
THM_LTR31_VLV1_TMP	LTR_13.9902	16.7	17	0	16.9	17	0	16.6	17	0
THM_LTR31_VLV2_TMP	LTR_13.9902	16.9	17	0	17.0	17	0	17.0	17	0
THM_LTR32_CATBED_TMP	LTR_15.9912	-34.5	-34	1	32.6	22	-10	-37.1	-40	-2
THM_LTR32_VLV1_TMP	LTR_15.9902	16.4	17	1	16.8	17	1	16.3	17	1
THM_LTR32_VLV2_TMP	LTR_15.9902	16.7	17	1	16.9	17	0	16.6	17	0
THM_GHETNK1_LAE2_TMP	MAIN.2701	14.3	13	-2	15.7	15	-1	0.7	1	0
THM_GHETNK1_LAE3_TMP	MAIN.2701	14.3	13	-2	15.6	15	-1	0.6	1	0
THM_GHETNK1_OUTLET1_TMP	MAIN.651050	13.1	13	-1	15.1	15	0	0.5	1	0
THM_GHETNK2_LAE2_TMP	MAIN.2801	14.4	12	-2	18.5	16	-3	2.1	1	-1
THM_GHETNK2_LAE3_TMP	MAIN.2801	14.4	12	-2	18.6	16	-3	2.2	1	-1
THM_GHETNK2_OUTLET1_TMP	MAIN.651094	13.8	12	-1	18.7	16	-3	2.4	1	-1
THM_HYDTNK_LOWEND1_TMP	MAIN.2468	20.4	21	0	20.7	20	-1	20.7	21	0
THM_HYDTNK_LOWEND2_TMP	MAIN.2476	20.2	21	0	20.5	21	0	20.3	21	0
THM_HYDTNK_SIDE3_TMP	MAIN.2433	20.3	21	1	20.3	20	0	20.4	20	0
THM_HYDTNK_SIDE4_TMP	MAIN.2439	21.0	21	0	21.4	21	-1	21.8	21	-1
THM_HYDTNK_UPEND5_TMP	MAIN.2406	20.5	21	1	20.8	21	0	20.9	21	0
THM_HYDTNK_UPEND6_TMP	MAIN.2412	20.3	21	1	20.4	21	1	20.4	21	1
THM_HYDTNK_DOME7_TMP	MAIN.2409	20.5	21	0	20.7	20	0	20.9	20	0
THM_HYDTNK_DOME8_TMP	MAIN.2415	20.6	21	0	20.8	20	0	21.0	20	-1
THM_HYDTNK_CYLNDR9_TMP	MAIN.2436	20.5	22	1	20.8	21	1	21.0	22	1
THM_HYDTNK_CYLNDR10_TMP	MAIN.2442	20.5	22	1	20.7	21	0	20.9	21	1

PSTM Correlation – Temperatures 5

TT Mnemonic	Corresponding Node	WSEOL TT	WSEOL Predict (°C)	WSEOL Delta (°C)	SSEOL TT	SSEOL Predict (°C)	SSEOL Delta (°C)	AEBOL TT	AEBOL Predict (°C)	AEBOL Delta (°C)
THM_HYDTNK_OUTFLO11_TMP	MAIN.2464	20.3	21	0	20.6	20	0	20.5	21	0
THM_HYDTNK_OUTFLO12_TMP	MAIN.2472	20.3	21	0	20.6	20	0	20.5	21	0
THM_OXTNK_BOTTOM_PX1_TMP	MAIN.2561	20.6	21	0	21.0	22	1	20.7	21	0
THM_OXTNK_BOTTOM_PX2_TMP	MAIN.2567	20.5	21	0	20.9	21	0	20.5	20	0
THM_OXTNK_TOP_PX3_TMP	MAIN.2511	20.6	21	0	20.5	21	0	20.5	21	0
THM_OXTNK_TOP_PX4_TMP	MAIN.2517	20.7	21	0	20.6	20	0	20.7	20	0
THM_OXTNK_BOTTOM_MX1_TMP	MAIN.2661	20.7	21	0	20.7	21	0	20.6	21	0
THM_OXTNK_BOTTOM_MX2_TMP	MAIN.2667	20.6	21	0	20.6	21	0	20.5	21	0
THM_OXTNK_TOP_MX3_TMP	MAIN.2611	20.8	21	0	20.8	20	-1	20.8	20	0
THM_OXTNK_TOP_MX4_TMP	MAIN.2617	20.8	21	0	20.8	21	0	20.8	21	0

PSTM Correlation – Heaters 1

	WSEOL			SSEOL			AEBOL		
Heater Mnemonic	Telemetry	Predict (°C)	Delta (°C)	Telemetry	Predict (°C)	Delta (°C)	Telemetry	Predict (°C)	Delta (°C)
THM_RCS_ISO_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_ISO_LN_PRI	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_LAEFLW_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_LAEFLW_LN_PRI	23.3	25	2	37.4	28	-9	43.7	37	-6
THM_RCS_LAETF_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_LAETF_LN_PRI	10.7	14	3	24.9	14	-11	27.1	20	-8
THM_RCS_MX_BS_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_MX_BS_LN_PRI	51.2	35	-16	36.7	50	14	80.5	56	-25
THM_RCS_MX_LIQ_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_MX_LIQ_LN_PRI	26.1	25	-1	11.6	17	5	32.3	32	0
THM_RCS_MX_VPR_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_MX_VPR_LN_PRI	50.8	43	-8	43.0	43	0	41.3	33	-8
THM_RCS_MYMX_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_MYMX_LN_PRI	17.8	26	8	9.8	25	15	21.4	32	10
THM_RCS_MYPX_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_MYPX_LN_PRI	10.7	9	-1	25.1	22	-4	26.7	34	7
THM_RCS_PRES_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0

This says "° C" but is really "DC%"

PSTM Correlation – Heaters 2

	WSEOL			SSEOL			AEBOL		
Heater Mnemonic	Telemetry	Predict (°C)	Delta (°C)	Telemetry	Predict (°C)	Delta (°C)	Telemetry	Predict (°C)	Delta (°C)
THM_RCS_PRES_LN_PRI	40.9	34	-7	29.6	37	8	52.4	48	-4
THM_RCS_PX_BS_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_PX_BS_LN_PRI	54.7	40	-15	32.1	20	-12	92.9	64	-29
THM_RCS_PX_LIQ_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_PX_LIQ_LN_PRI	30.3	41	11	45.4	53	8	57.2	63	6
THM_RCS_PX_VPR_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_PX_VPR_LN_PRI	13.4	15	2	22.4	53	30	24.9	23	-2
THM_RCS_PYMX_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_PYMX_LN_PRI	17.8	9	-8	13.4	23	10	27.1	22	-5
THM_RCS_PYPX_LN_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_RCS_PYPX_LN_PRI	10.7	9	-2	28.5	33	5	28.8	28	-1
THM_AJT13_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_AJT13_VLV_PRI	45.4	44	-1	0.0	0	0	47.4	46	-1
THM_AJT14_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_AJT14_VLV_PRI	47.9	47	-1	0.0	0	0	48.9	49	0
THM_AJT15_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_AJT15_VLV_PRI	0.0	0	0	42.8	42	-1	44.4	44	0
THM_AJT16_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_AJT16_VLV_PRI	0.0	0	0	44.5	43	-2	45.3	45	-1
THM_LAE_INJECT_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LAE_INJECT_PRI	0.0	0	0	0.0	0	0	43.1	0	-43
THM_LAE_OXHYD_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LAE_OXHYD_VLV_PRI	28.5	9	-19	19.6	6	-14	0.0	0	0
THM_HBT02_INJECT_BU	100.0	99	-1	29.6	0	-30	0.0	0	0
THM_HBT02_INJECT_PRI	45.2	45	0	0.0	0	0	0.0	0	0
THM_HBT02_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_HBT02_VLV_PRI	0.0	0	0	0.0	0	0	34.7	30	-5
THM_HBT03_INJECT_BU	100.0	99	-1	0.0	0	0	0.0	0	0
THM_HBT03_INJECT_PRI	51.4	51	-1	0.0	0	0	0.0	0	0
THM_HBT03_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_HBT03_VLV_PRI	0.0	0	0	0.0	0	0	33.3	30	-3
THM_REA05_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA05_VLV_PRI	31.8	31	-1	3.6	5	1	36.0	42	6
THM_REA06_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0

This says "° C" but is really "DC%"

PSTM Correlation – Heaters 3

Heater Mnemonic	WSEOL Telemetry	WSEOL Predict (°C)	WSEOL Delta (°C)	SSEOL Telemetry	SSEOL Predict (°C)	SSEOL Delta (°C)	AEBOL Telemetry	AEBOL Predict (°C)	AEBOL Delta (°C)
THM_REA06_VLV_PRI	30.4	27	-4	5.3	2	-3	34.2	35	1
THM_REA07_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA07_VLV_PRI	23.2	21	-2	0.0	0	0	21.7	28	6
THM_REA08_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA08_VLV_PRI	23.2	22	-2	0.0	0	0	23.2	28	5
THM_REA09_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA09_VLV_PRI	23.2	21	-3	0.0	1	1	33.9	34	0
THM_REA10_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA10_VLV_PRI	22.4	20	-2	0.0	2	2	35.6	34	-1
THM_REA11_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA11_VLV_PRI	22.4	23	1	7.1	7	-1	33.9	40	6
THM_REA12_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_REA12_VLV_PRI	22.4	23	1	7.1	7	0	34.6	40	6
THM_LTR17_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR17_VLV_PRI	21.4	17	-4	0.0	9	9	21.7	19	-2
THM_LTR18_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR18_VLV_PRI	24.1	17	-7	0.0	9	9	26.2	19	-7
THM_LTR19_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR19_VLV_PRI	0.0	10	10	26.0	15	-11	26.7	19	-8
THM_LTR20_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR20_VLV_PRI	0.0	10	10	26.9	16	-11	28.8	19	-9
THM_LTR21_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR21_VLV_PRI	0.0	10	10	25.0	13	-12	24.9	18	-7
THM_LTR22_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR22_VLV_PRI	0.0	10	10	24.1	13	-11	26.7	18	-8
THM_LTR23_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR23_VLV_PRI	26.7	16	-11	0.0	8	8	26.7	19	-8
THM_LTR24_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR24_VLV_PRI	24.1	16	-8	0.0	8	8	24.9	19	-6
THM_LTR25_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR25_VLV_PRI	2.7	10	8	16.0	10	-6	21.4	19	-3
THM_LTR26_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR26_VLV_PRI	0.0	9	9	18.9	15	-4	20.4	19	-2
THM_LTR27_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0

This says "° C" but is really "DC%"

PSTM Correlation – Heaters 4

	WSEOL			SSEOL			AEBOL		
Heater Mnemonic	Telemetry	Predict (°C)	Delta (°C)	Telemetry	Predict (°C)	Delta (°C)	Telemetry	Predict (°C)	Delta (°C)
THM_LTR27_VLV_PRI	5.3	7	1	35.8	21	-15	37.8	23	-15
THM_LTR28_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR28_VLV_PRI	8.0	8	0	35.6	17	-18	40.0	23	-17
THM_LTR29_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR29_VLV_PRI	18.7	16	-3	2.7	9	6	21.4	20	-2
THM_LTR30_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR30_VLV_PRI	18.1	13	-5	0.0	7	7	21.6	18	-4
THM_LTR31_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR31_VLV_PRI	21.4	12	-9	16.0	15	-1	37.3	23	-14
THM_LTR32_VLV_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_LTR32_VLV_PRI	21.4	12	-9	16.0	15	-1	36.4	23	-13
THM_PX_OX_TNK_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_PX_OX_TNK_PRI	7.1	8	1	7.1	11	4	16.0	14	-2
THM_MX_OX_TNK_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_MX_OX_TNK_PRI	8.0	10	2	8.0	9	1	16.0	15	-1
THM_HYD_TNK_1_TOP_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_HYD_TNK_1_TOP_PRI	15.1	11	-4	15.1	15	0	28.0	18	-10
THM_HYD_TNK_2_MID_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_HYD_TNK_2_MID_PRI	3.6	10	7	3.6	11	8	10.7	14	3
THM_HYD_TNK_3_BT1_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_HYD_TNK_3_BT1_PRI	0.0	7	7	0.0	0	0	0.0	6	6
THM_HYD_TNK_4_BT2_BU	0.0	Not Modelled	0	0.0	Not Modelled	0	0.0	Not Modelled	0
THM_HYD_TNK_4_BT2_PRI	0.0	0	0	0.0	6	6	0.0	6	6

This says "° C" but is really "DC%"

PSTM Correlation Summary

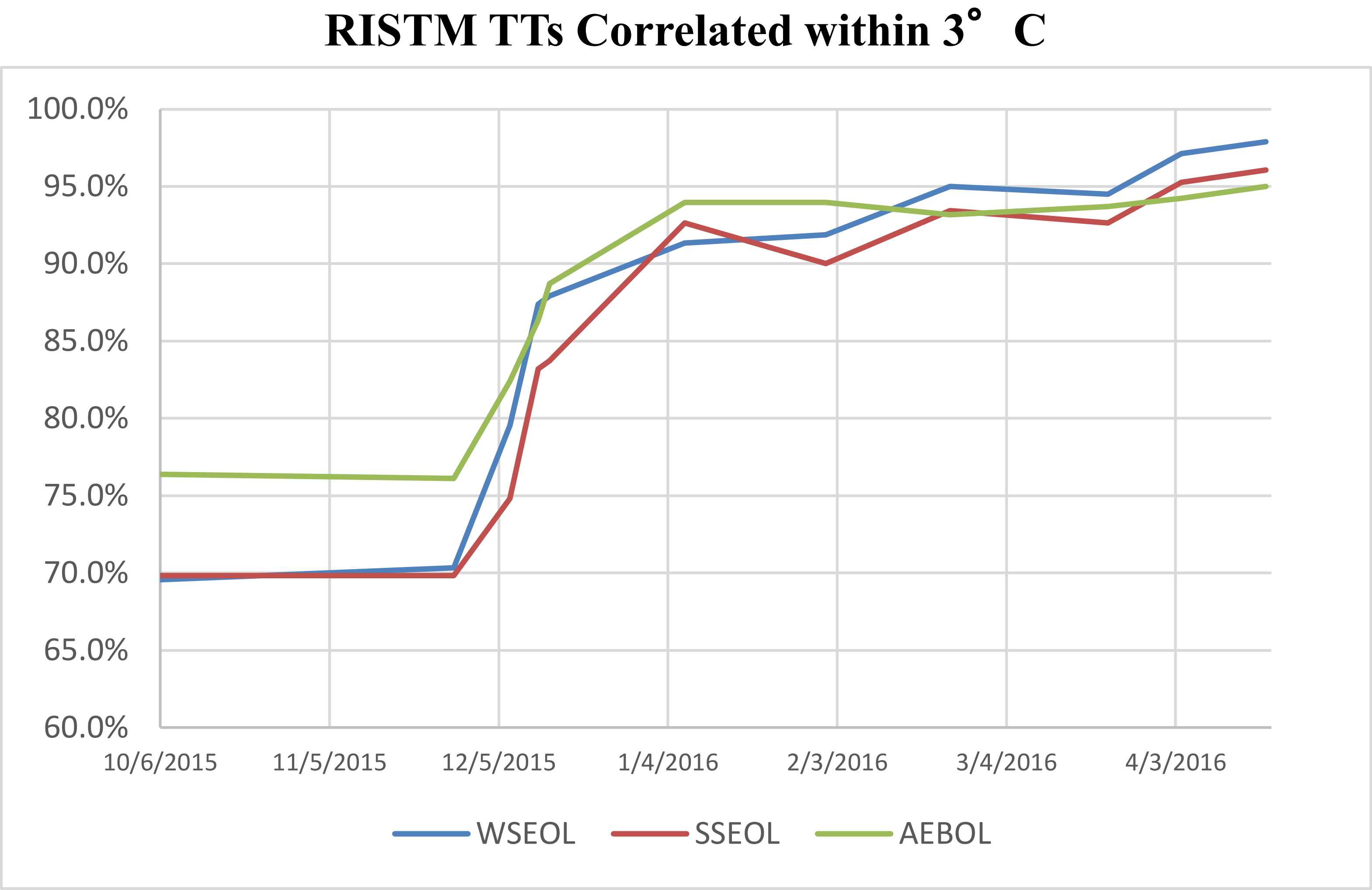
- Again, over 500 changes made to the PSTM during correlation process – this model didn't exist before pre-SCT (at PER), so this was expected.
- Biggest cause of errors are inaccurate thruster/engine sub-models (HBTs, AJs, LAE)

LL 5

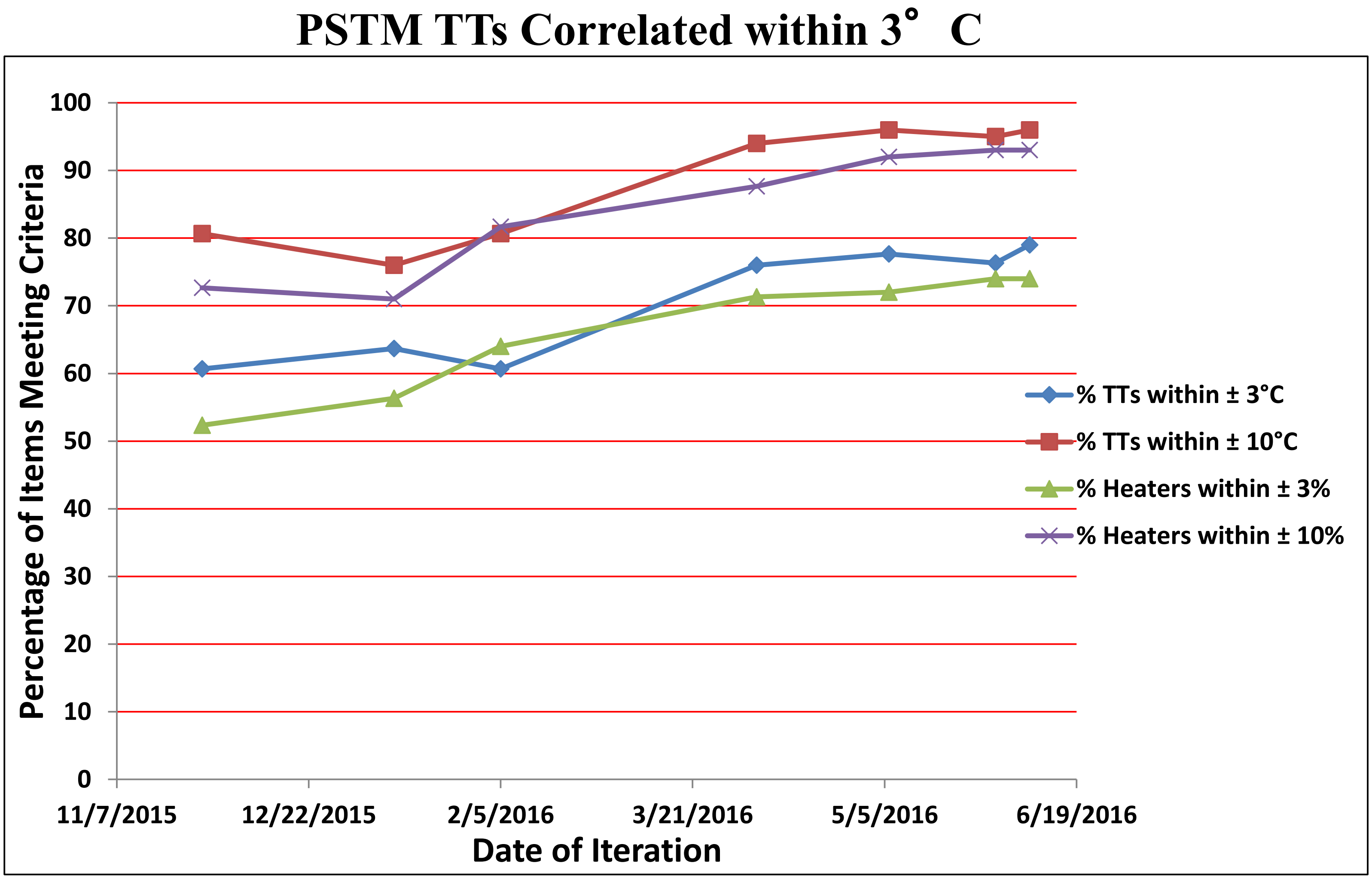
Group	Criteria	WSEOL	SSEOL	AEBOL
RCS Lines	% TTs within ± 3°	55%	55%	59%
	% TTs within ± 10°	100%	98%	98%
Arc Jets	% TTs within ± 3°	50%	75%	92%
	% TTs within ± 10°	100%	92%	100%
REAs	% TTs within ± 3°	100%	75%	100%
	% TTs within ± 10°	100%	75%	100%
LTRs	% TTs within ± 3°	83%	79%	98%
	% TTs within ± 10°	96%	90%	100%
HBTs	% TTs within ± 3°	25%	50%	50%
	% TTs within ± 10°	50%	100%	100%
LAE	% TTs within ± 3°	33%	33%	0%
	% TTs within ± 10°	100%	100%	67%
Tanks	% TTs within ± 3°	100%	100%	100%
	% TTs within ± 10°	100%	100%	100%
Total	**% TTs within ± 3°**	**73%**	**72%**	**81%**
	% TTs within ± 10°	**96%**	**93%**	**98%**

Group	Criteria	WSEOL	SSEOL	AEBOL
RCS Lines	% HDCs within ± 3%	68%	52%	60%
	% HDCs within ± 10%	88%	80%	88%
Arc Jets	% HDCs within ± 3%	100%	100%	100%
	% HDCs within ± 10%	100%	100%	100%
REAs	% HDCs within ± 3%	94%	100%	69%
	% HDCs within ± 10%	100%	100%	100%
LTRs	% HDCs within ± 3%	59%	56%	63%
	% HDCs within ± 10%	94%	81%	88%
HBTs	% HDCs within ± 3%	100%	88%	75%
	% HDCs within ± 10%	100%	88%	100%
LAE	% HDCs within ± 3%	75%	75%	75%
	% HDCs within ± 10%	75%	75%	75%
Tanks	% HDCs within ± 3%	75%	75%	67%
	% HDCs within ± 10%	100%	100%	100%
Total	**% HDCs within ± 3%**	**75%**	**70%**	**68%**
	% HDCs within ± 10%	**94%**	**88%**	**92%**

RISTM Correlation Progress



Prop Model Correlation Progress



Final Correlation Results

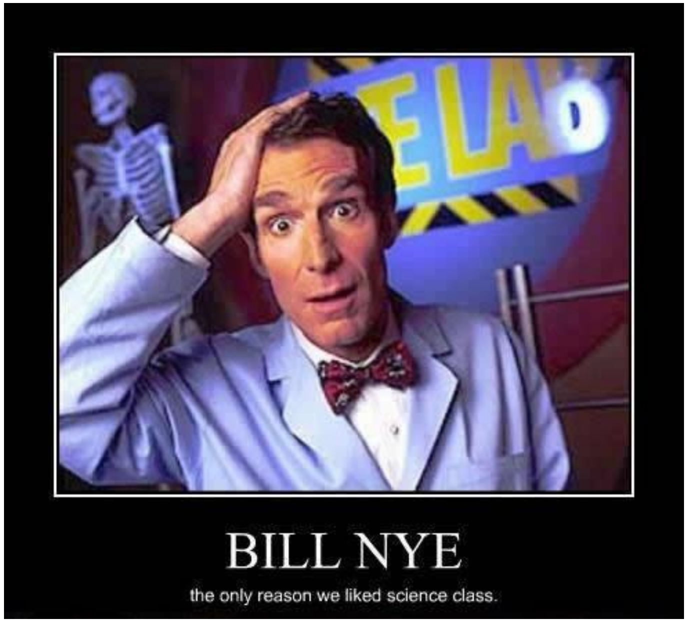
- Correlation criteria
  - “The correlated analytical model shall be accurate to within 5° C for all “relevant” spacecraft bus hardware and 3° C for all “relevant” instrument hardware. “Relevant” hardware is defined as all hardware with flight temperature limits.”
- Waiver generated for all temperature sensors or heaters not correlated to the criteria listed above
  - GOES-VR1-16-0516
  - Refer to “GOES-R_Model_Prediciton_Exceedances.xlsx” for detailed list of exceedances with justification

Model	Component Category	Correlation Result
RISTM	Temperature sensors	336 of 353 (95%) within criteria for all cases
	Heaters	105 of 137 (77%) within criteria for all cases
Propulsion	Temperature sensors	106 of 160 (66%) within criteria for all cases
	Heaters	67 of 108 (62%) within criteria for all cases

Overall Excellent Correlation Effort

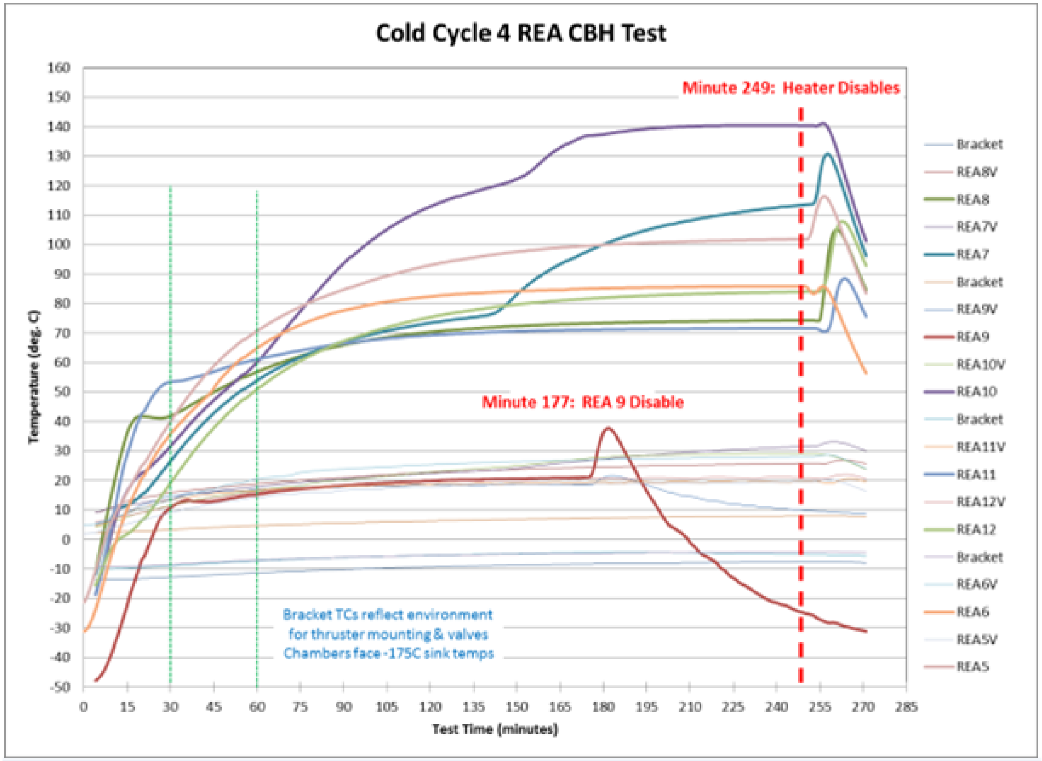
Test Discoveries/Lessons Learned

Watrods,
Additional MLI
REAs,
Transistors
Unit repair/retest



Test "Discoveries": REA Cat Bed Heaters

- Pre-fire warm-up heaters on 5lb REAs showed inconsistent temperature response. Thought to be instrumentation issue (TCs were "taped" on, and no flight telemetry).
  - **Inflections in the warmup trends were not readily explained simply by "TC issue".**
  - **The warmup tests were performed both at hot and cold plateaus.**



LL 6

Warm-up Temperature Reduced

Test "Discoveries": 5 more

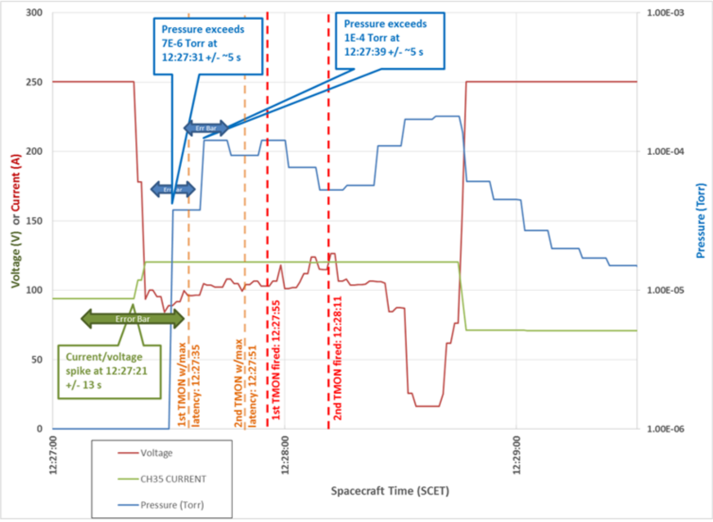
- Solar Array Simulator Cable Overheating: during pumpdown prior to cold shroud.
  - Cause: low priority EGSE, little effort to control temperature
  - Disposition: Unblanket of better distribute for future SCTVs.

LL 7

- Calpod Overheating: aluminized Kapton wrap more effective and dissipation slightly more than estimated.
  - Cause: low priority EGSE; little effort to control temperature
  - Disposition: open radiator "window" for future SCTVs.
- Chamber control/data system (various):
  - Cause: New….even though there was a "chamber cert" pre-test.
  - Disposition: continued use will resolve many/most issues.
- Low SPP Heater Plate Temperature: MZ heater plate of the SPP PX1 zone was consistently colder than the PZ heater plate.
  - Cause: combined circuits on 2 plates with different views to shroud.
  - Disposition: separate circuits for next vehicle test.
- Large RCS Vapor Line Gradient: multiple sensors, with hottest hitting RED limit of 85° C.
  - Cause: Test configuration did not have MLI in place on pyro valve, resulting in cold biased sensor group average and "full on" heater.
  - Disposition: add MLI for future tests, or take sensor out of group average. This MLI will be in place for flight.

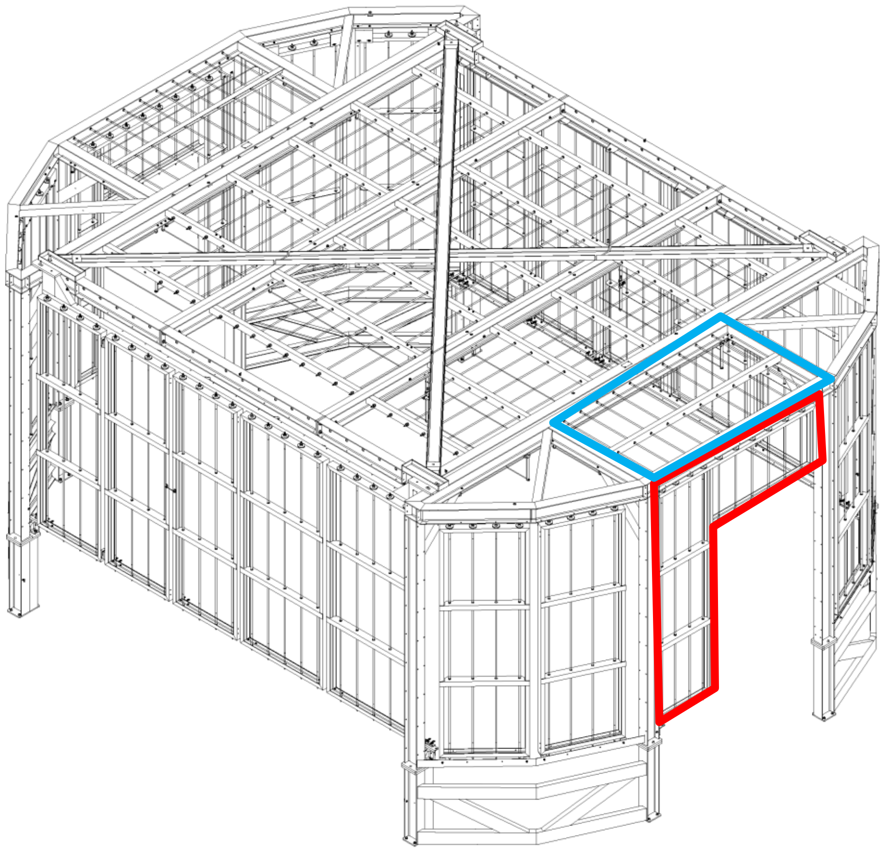
Test “Discoveries”: Watrod Short

- On Day 17 of the test, spacecraft was in transition to Hot Cycle 2, along with MGSE heaters, including a GLM MGSE heater and the WatRod (MGSE) heaters.
- A chamber pressure event occurred 7/17/15, reaching a peak of 1.38 x 10-4 torr from a base of 1.00 x 10-6. (pressure excursion: 6:28:48 to 6:48:47).
  - High voltage shutdown as planned
  - Chamber recovered & test continued for another 38 days.
- FRB was held and at the time and concluded that a bubble under the heater or some other entrapped air pocket escaped and caused a momentary pressure spike - authorized continuation of the test
  - A heater supply current spike occurred at the time of the event but was not uncovered until post-TVAC.
  - A temperature spike was also observed on a thermocouple located on the GLM baffle. Suggesting that a local “temperature event” had occurred.
- On 8/24/15 following completion of the test, damaged wiring, damaged baffle material, soot, copper orbs, and discolored surfaces were observed within the TVAC Chamber. An FRB was convened to control access and activity and retain evidence.



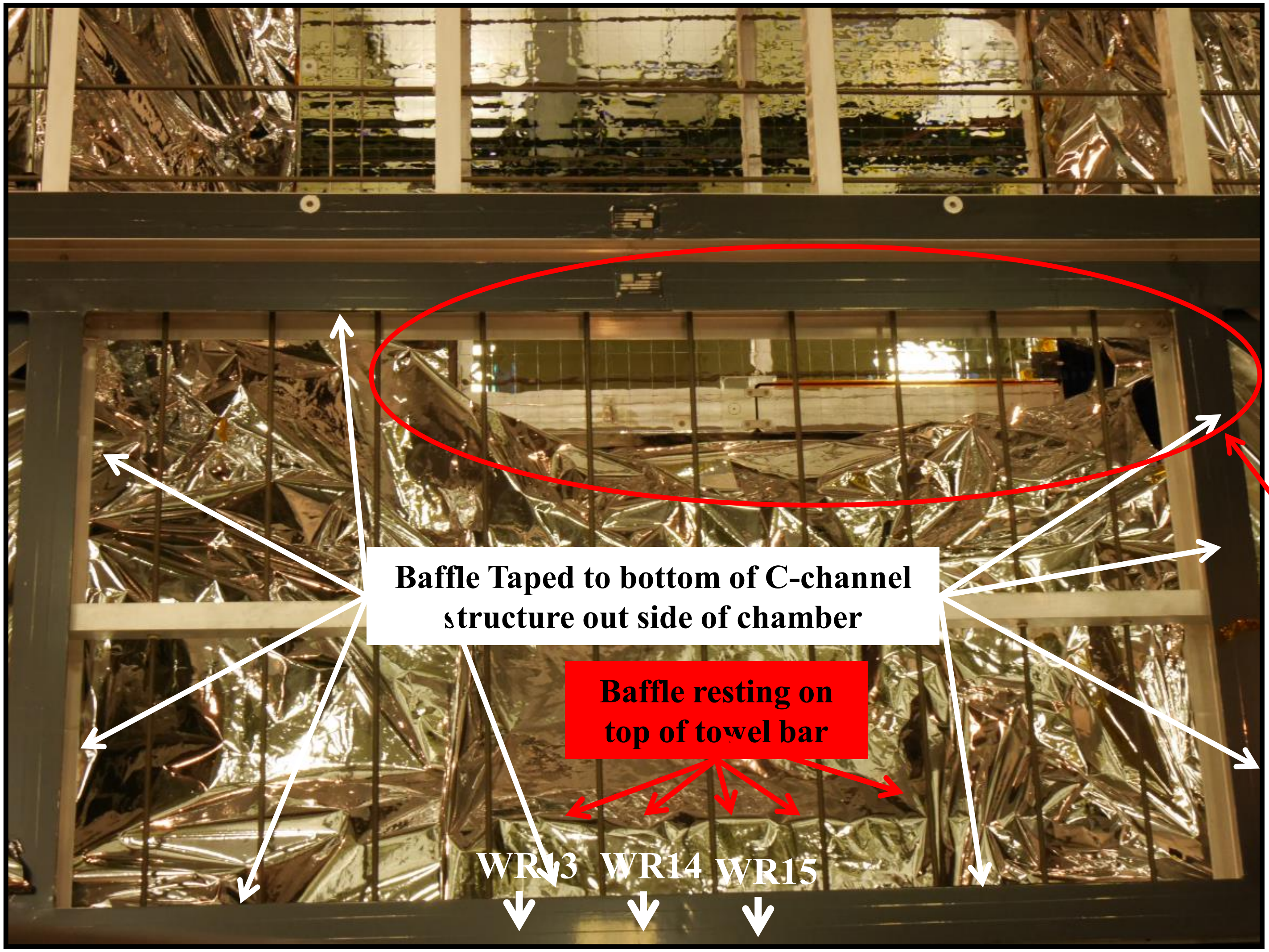
Which Watrods ?

Anomaly Area Zone “PZ”



- **Image on left is GOES TVAC Thermal Control Assembly**
- **Assembly is installed into the TVAC chamber in sections, over the installed spacecraft.**
- **The assembly is made up of aluminum “window frames” with WatRod (CalRod) heating elements installed between the “window frames”. Sometimes referred to as the “Cage”**
- **The damage is confined to one end of the assembly (PZ Zone) identified as one of the two “D” sections.**

MY section of PZ Zone installed

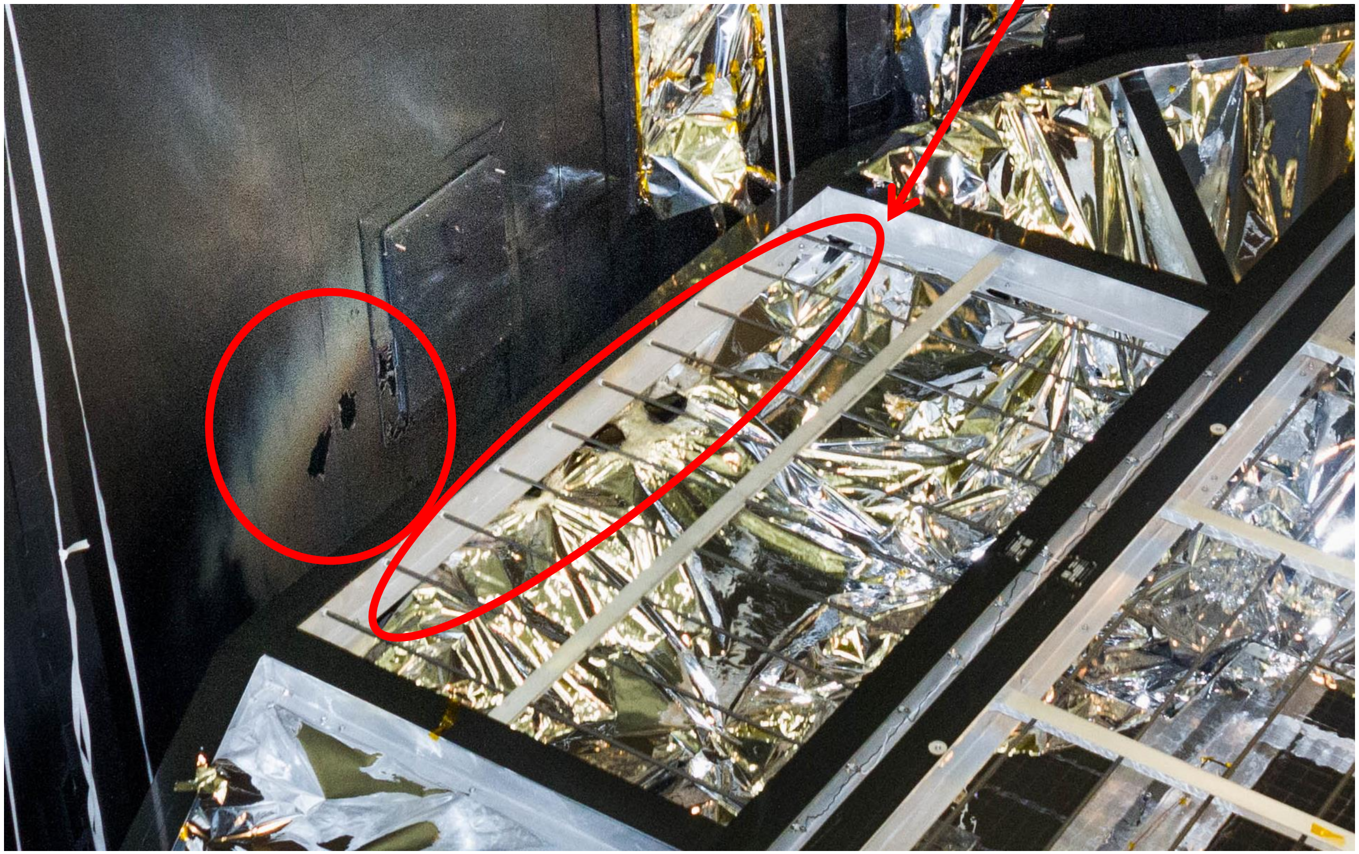


Top of Cage looking down (Blue outline on previous Slide)

Modified in chamber per Thermal Engineering Direction

Post Event picture inside chamber

Image of similar area in last slide after TVAC Showing damage to baffle and contamination to baffle and shroud

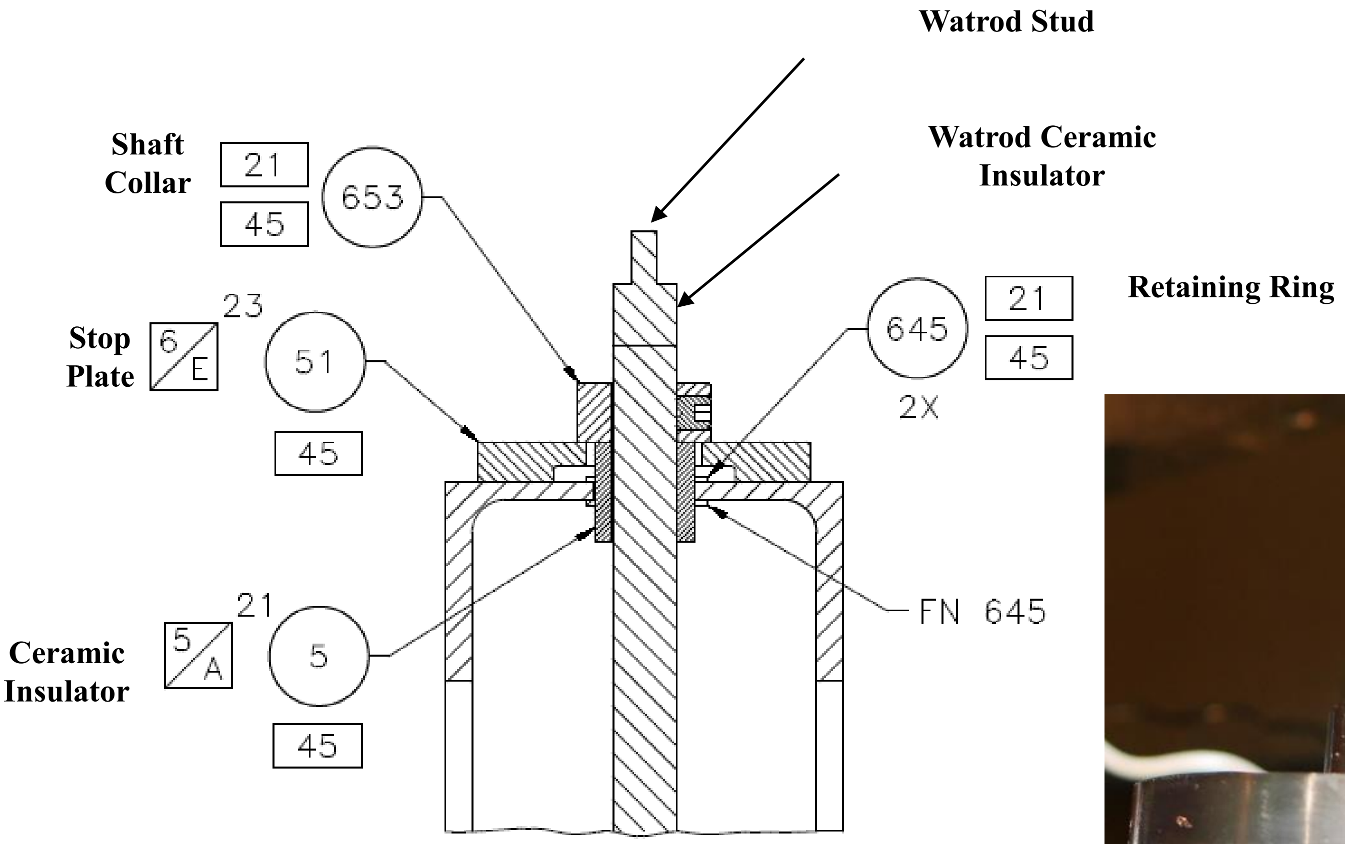


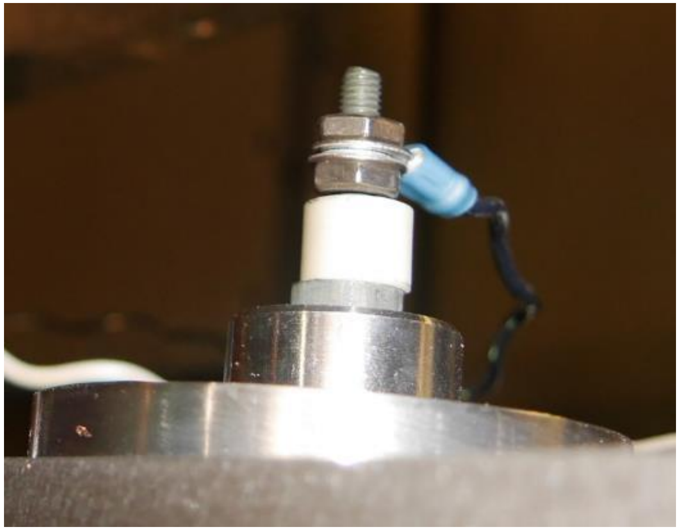
Damaged Area Outside of Chamber

WR15 WR14 WR13

Most destruction and hottest area appears to be at the top of zone PZ, center section.

Watrod Configuration



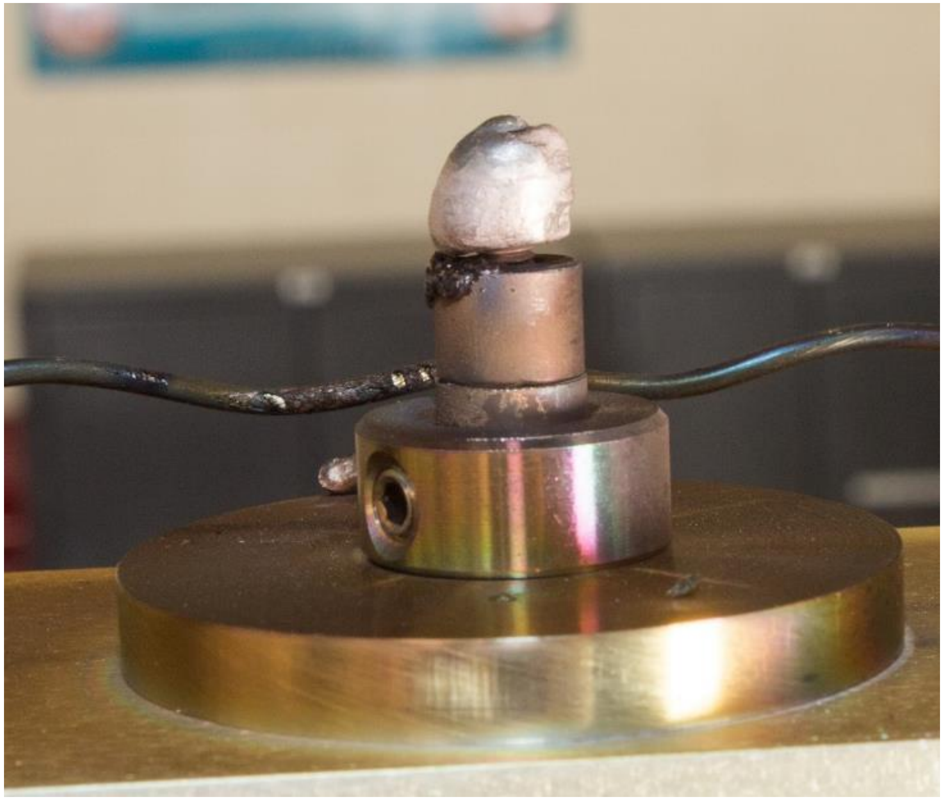


13. UNLESS OTHERWISE SPECIFIED TIGHTEN THE FASTENER TO ELIMINATE ALL LOOSENESS IN THE ASSEMBLY AND THEN TIGHTEN AN ADDITIONAL 1/6 (60 DEGREES) TURN TO COMPLETE THE TIGHTENING, EXCEPT THAT FASTENERS LESS THAN 1/4 INCH IN DIAMETER MAY BE TIGHTENED LESS THAN 1/6 TURN TO AVOID DAMAGE OR SHEARING FROM OVER TIGHTENING.

Watrod 14 and 15 Post Event

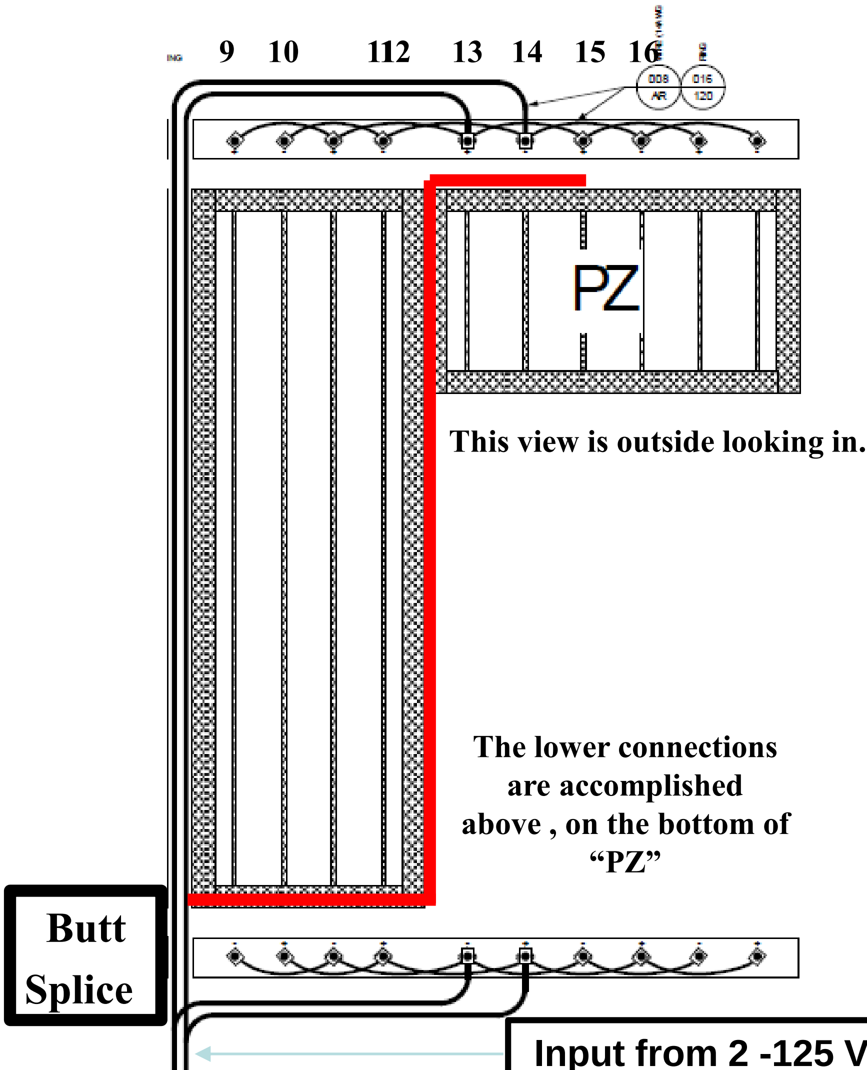
- The posts, nuts, washer, ring lug at the top of the Watrod appears to have seen the highest temperature fusing metal parts.

Watrod 14



Watrod 15

Zone PZ Circuit Diagram (Part 1)



The Numbers along the top are the identifiers for the Watrods

Damaged wire location shown in Red
Likely starting point at WR14 /15
Vaporized wiring from WR13/14 and down the frame

The wire damaged was 14 AWG Copper w/silver plate & Teflon (PTFE) jacket Twisted Pair (Wht/Blk) assessed as 38 Amp capable but derated to 19 Amp for TVac application (actual wire pair carried 10.5 amp nominal). 120 Amp application during this event.

Input from 2 -125 VDC Power Supplies wired in series providing 250 VDC

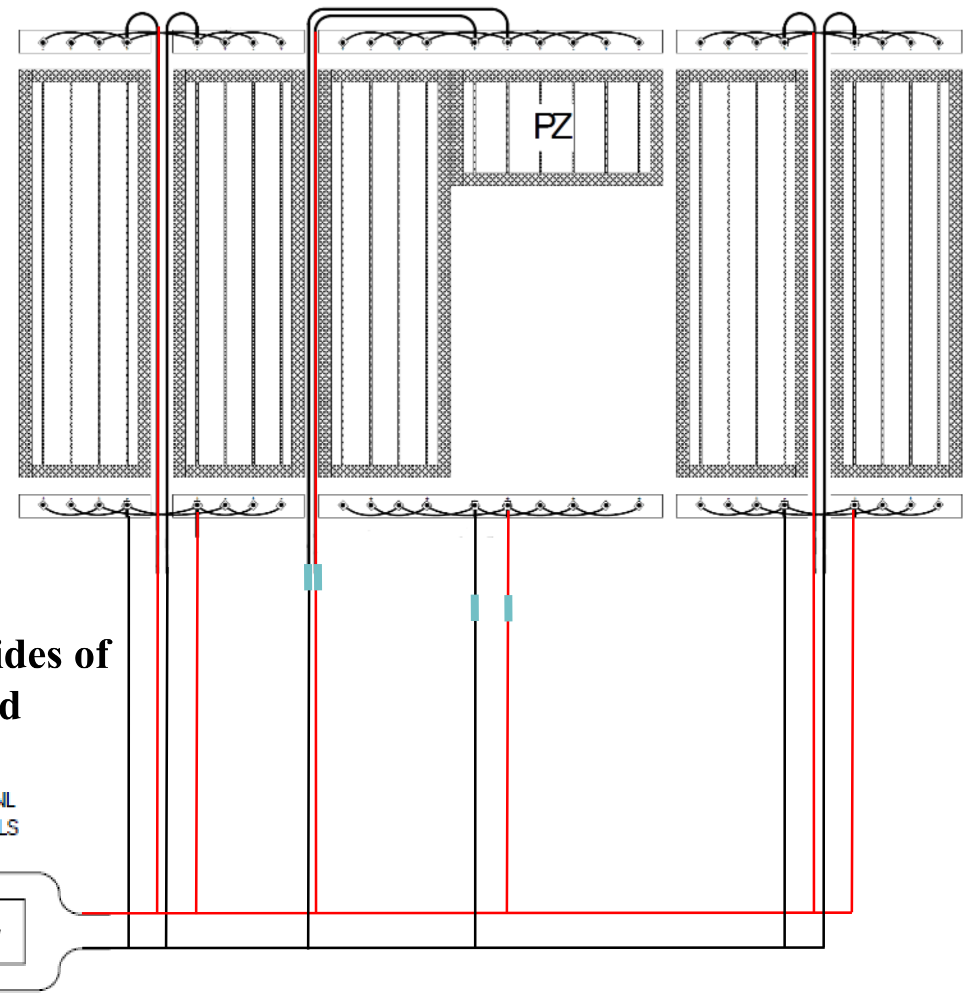
Schematic of WatRod EGSE circuit To power supply.

— **Indicates Splice added post-bakeout**

"Red" = Positive
"Black = Negative

Note: Frame was grounded and both sides of power supply isolated from ground

SYSTEM POWER CHANNEL	RACK	LOOP	CURRENT LIMIT	VOLTAGE LIMIT	PWR CHNL TERMINALS
35	5	PS3	95.0A	100%	CH35+ CH35-
36	5	PS4	95.0A	100%	CH36+ CH36-



WR's 13-15 post event (in chamber)

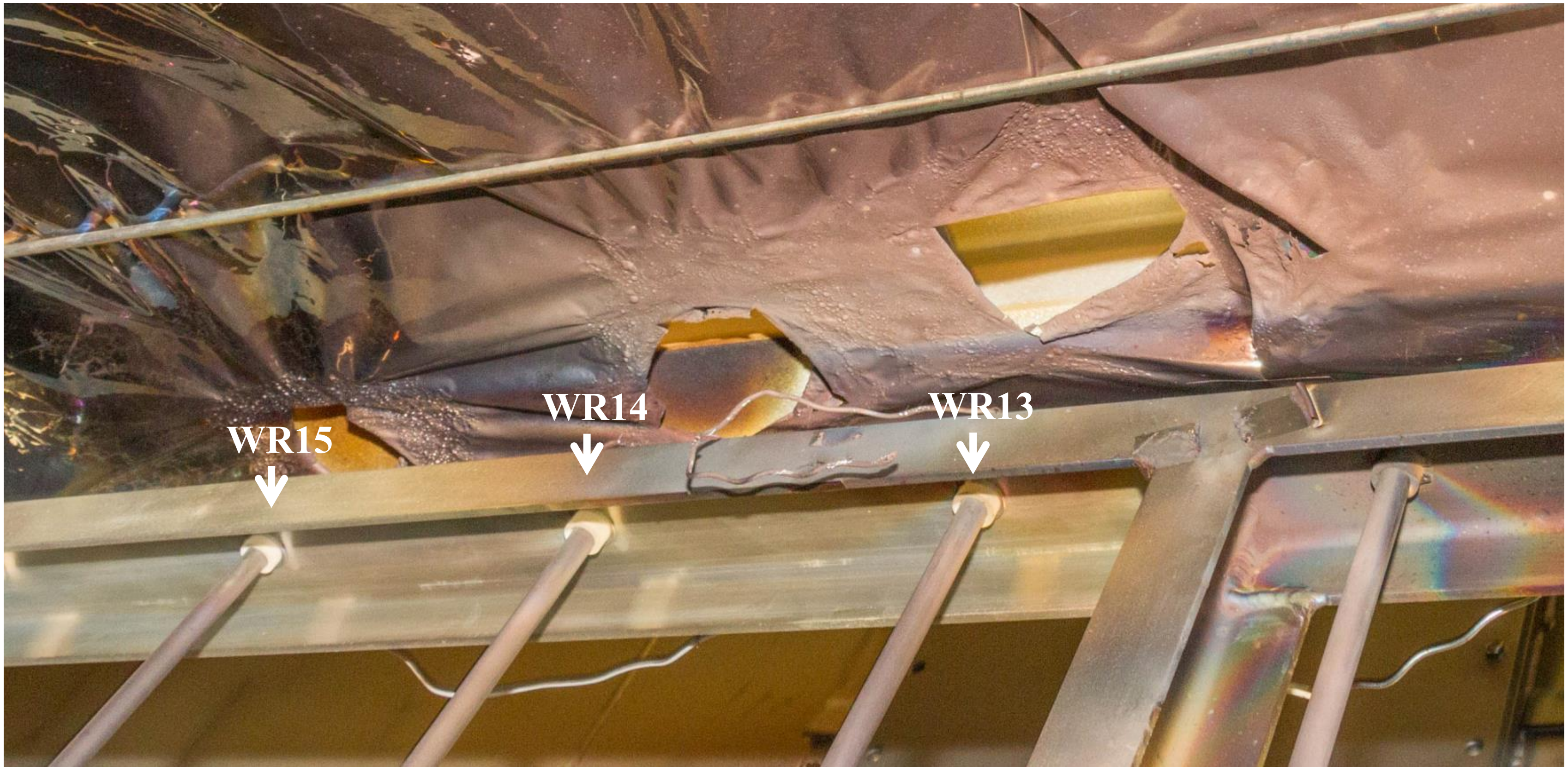
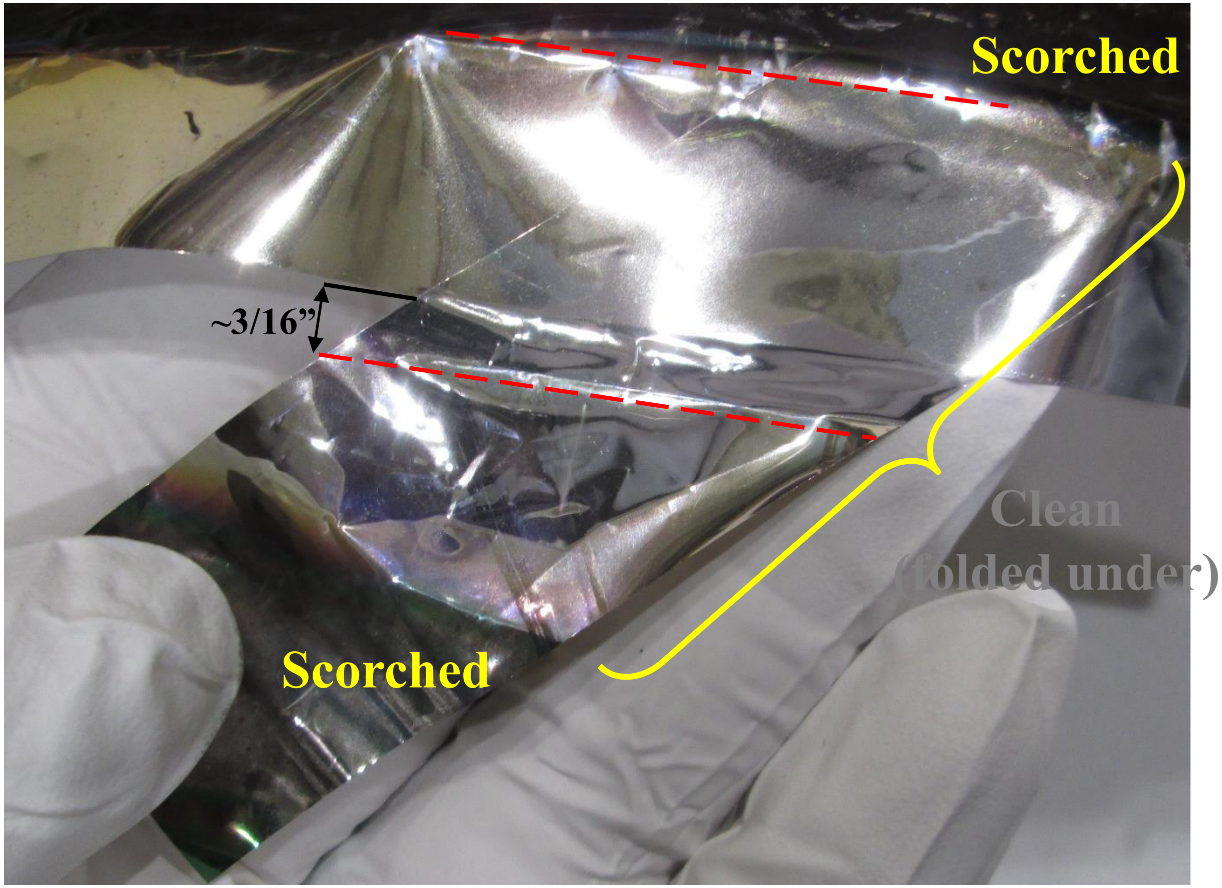
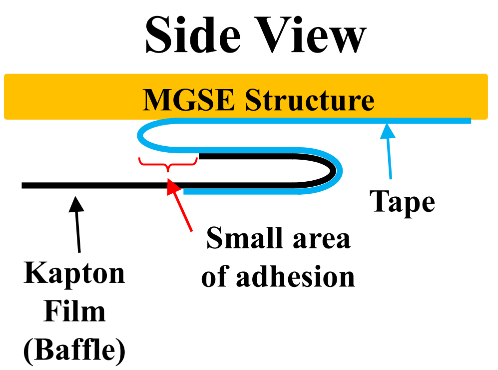


Image above shows that the baffle material was sagging and encroaching on the MGSE structure near the terminals of the WatRods

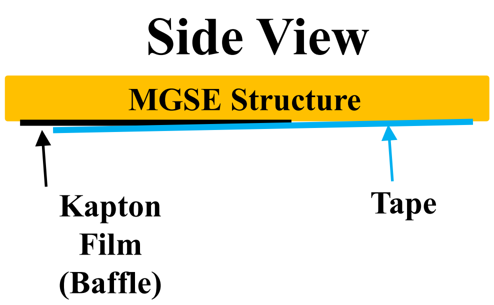
Configuration of how the Baffled was taped to the MGSE structure



Actual Configuration



Should Be Configuration



Test "Discoveries": Battery DoD

- CDR thermal predictions based on unit dissipation estimates, with margin, per standard practice.
  - WS and SS BOL and EOL temperatures were above heater turn on temperatures, so no heater power reports.
  - AE cases report heater power, but was "reduced" by unit dissipations.
- These unit dissipations were never fully updated at PER, to incorporate unit level test measured power, and eliminate margins.

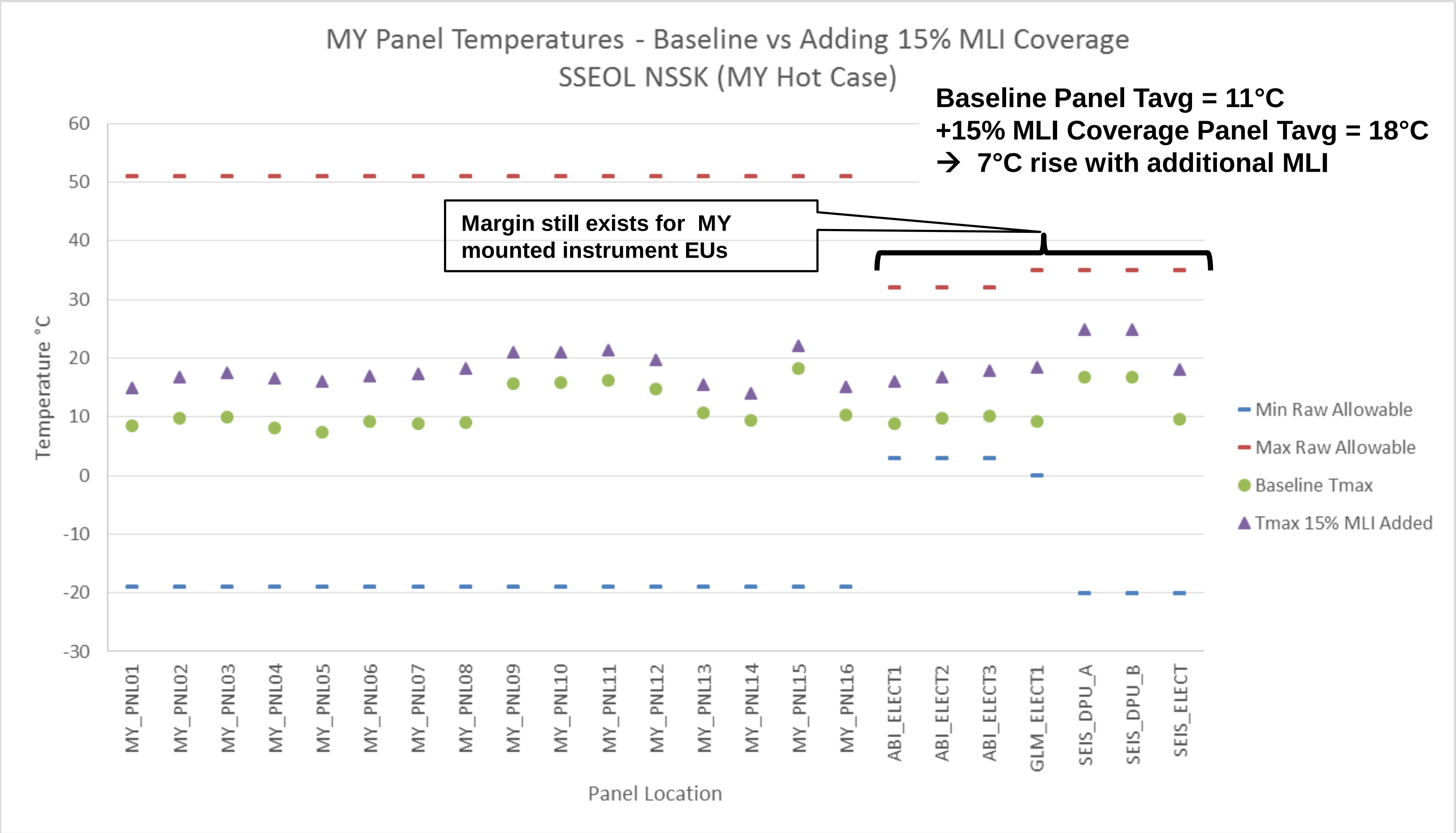
LL 8

  - Power budget had been updated and still had required DoD margins.
- Post-correlation of thermal models, that used reduced unit dissipations completed before PSR:
  - Temperatures on PY/MY panels reduced by ~20° C.
  - Heater power increased in all BOL cases: 700W+ in AEBOL case (Battery DoD design point).

Test Discoveries: Battery DoD (2)

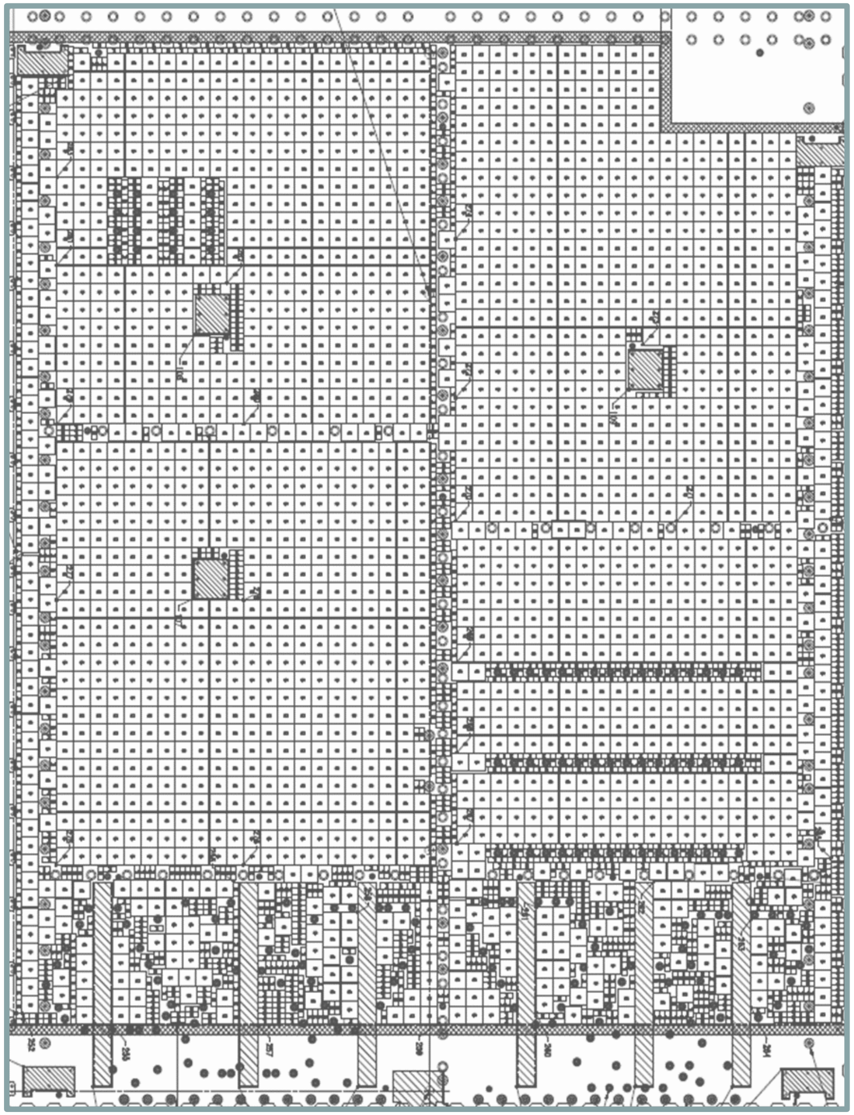
- Obvious solution was to add MLI to the large PY/MY panels.
  - PY: 18% area already covered (near edges)
  - MY: 13% area already covered (near edges)
  - Quick analysis had shown ~110W savings for 10% additional MLI coverage, on each panel.
- Implementation issues identified for PY side:
  - Just completed stowing solar array, covering this side in total.
  - Possible access around edges (which is where you'd add MLI anyway), but installation by "reaching in" under the array was considered an unacceptable risk.
- So only MY was targeted.
  - More refined analysis indicated 245W savings for 15% additional MLI coverage, which provided sufficient margin on Battery DoD.

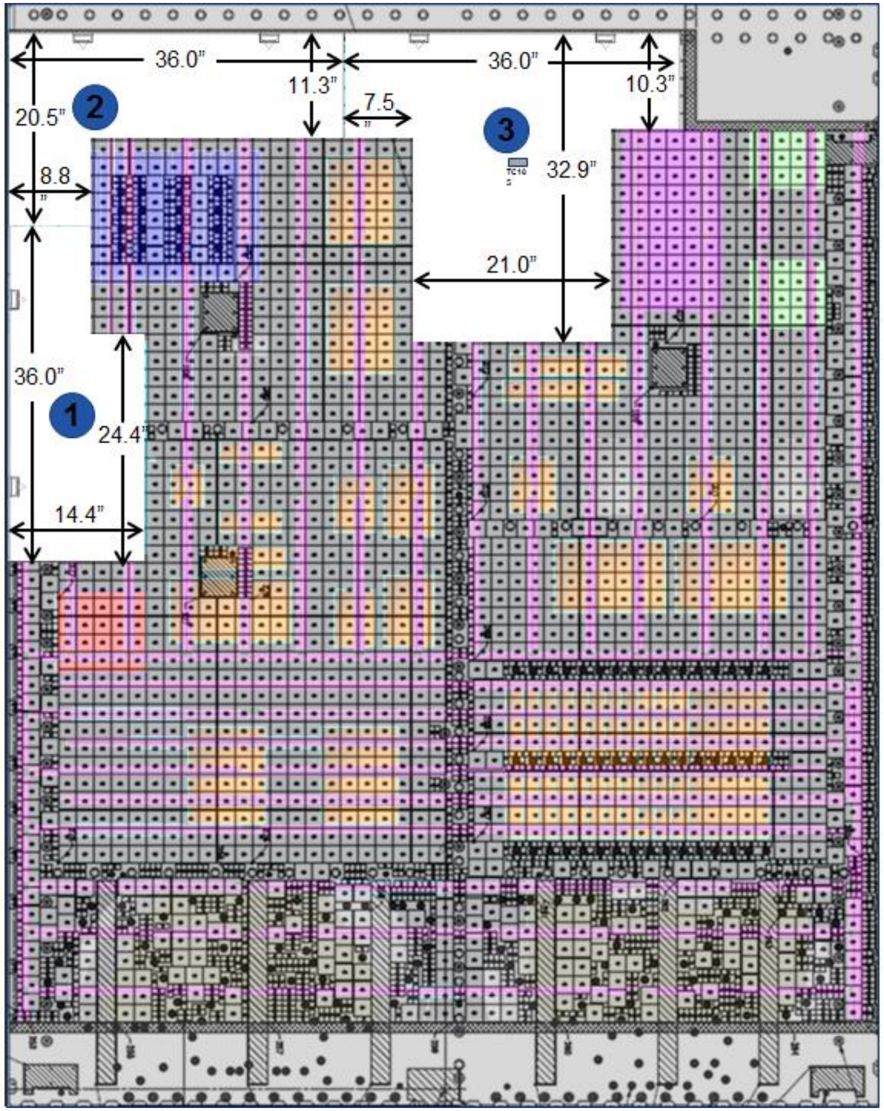
Expected Temperature Increase



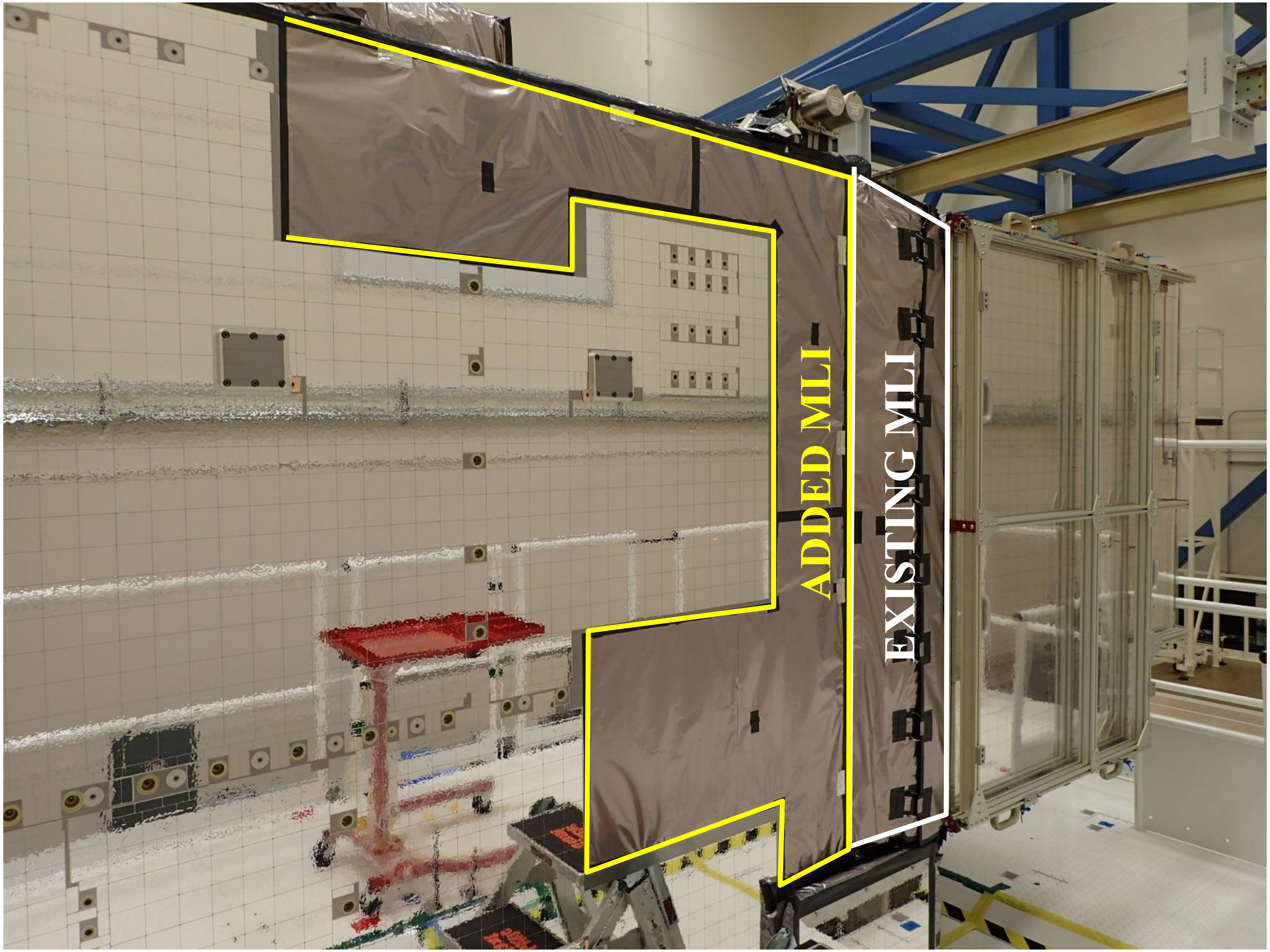
Baseline Panel Tavg = 11°C
+15% MLI Coverage Panel Tavg = 18°C
→ 7°C rise with additional MLI

New MLI Locations





Added MLI ("top" of MY Radiator)



Test "Discoveries": Electronics Failure

- On the 4th Cold Plateau, the Battery Charge/Discharge Module in the SPRU (Scalable Power Regulation Unit) failed.
  - In "standby" mode (not charging or discharging), but telemetry indicated an anomaly.
  - Subsequent investigation resulted in removal for R&R, which identified a transistor with a failed hermetic seal, with moisture absorption that froze during the cold soak, causing the failure.
- Satellite following GOES-R in same chamber, also experienced an unrelated part failure. Both of these parts issues were used on numerous –R and –S (in I&T) boxes.
- All units were removed, repaired and retested before re-integration….no repeat of –R system level test.

Pressure was on to reduce to 2 cycles to meet schedule – if not in subsequent ambient testing, this would have likely failed post-separation during cold transfer orbit in first week of mission.

Special Topic

Unit level rework

Premise

- Every project faces rework of an electronics unit at some point in the program.
- Depending on the point in the development and qualification cycles, the repaired/reworked unit must be retested. How many cycles ?
- MIL-STD-1540 does provide some guidance.
- GEVS does not….. at least as far as thermal verification of workmanship goes. To my knowledge, NASA does not have a documented standard on this topic,.
- Usually project says “2 or 3”, but on what basis ?? Because they did that on their last project? What if that project was a Class D mission or instrument, but this one is a lower risk classification ?
- Without any documented engineering basis, it is hard to refute “2 or 3”.
- While I consider this a reliability or risk assessment requirement, I have never seen an engineering basis for their numbers.

Background: Thermal Cycling Goals

- The goals of thermal cycling are:
  - To demonstrate performance over temperature extremes outside of the allowable range for the mission.
  - Provide sufficient Environmental Stress Screening (ESS): by exposing "a product" to an environment that causes the "weak" elements (latent defects) of an assembly to fail, using a relatively high transition rate and repetitive thermal transitions (cycles) over a temperature range outside the allowable operating temperature.
    - Protoflight margin: +/-10° C outside operating range

- Regression testing must be "engineered" to verifies that "a product" that was previously tested still performs correctly after it was "reworked", and it must also provide sufficient verification of the workmanship of the reworked portion.

- The goal of "regression testing" has to be to return the "product" to a sufficient state of "readiness" from an ESS and a performance trending point-of-view, that depends on the point in the build/assembly cycle that the rework took place.

What is the Basis for Determining Cycle Quantity??

GSFC: Thermal Cycling Requirements

- GOLD Rule 4.29 "All systems flying in unpressurized areas shall have been subjected to a minimum of eight (8) thermal-vacuum test cycles prior to installation on a spacecraft." (Reference GEVS 2.6.2.4.b)

- GEVS 2.6.2.4.b Cycling between temperature extremes has the purpose of checking performance during both stabilized conditions and transitions thereby causing temperature gradient shifts, thus inducing stresses intended to uncover incipient problems. The minimum number of thermal-vacuum temperature cycles for the payload, subsystem/instrument, and component levels of assembly are as follows: 4+4+4 =12

GSFC Philosophy is 12 {Protoflight Cycles Before Flight

GEVS: Verification Plan

- GEVS 2.1.1.1.1 Environmental Verification Plan
- An *environmental verification plan shall be prepared*, either as part of the System Verification Plan or as a separate document, that prescribes the tests and analyses that will collectively demonstrate that the hardware and software comply with the environmental verification requirements

- The *environmental verification plan* shall provide the overall approach to accomplishing the environmental verification program. For each test, it shall include the level of assembly, the configuration of the item, objectives, facilities, instrumentation, safety considerations, contamination control, test phases and profiles, necessary functional operations, personnel responsibilities, and requirement for procedures and reports. It shall also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity shall be described.

GEVS: Thermal Cycling Retest

- GEVS 2.3.4 Performance Operating Time and Failure-Free Performance Testing
  - During/after system level TV: "Also, the retest requirements following component failure during system level thermal vacuum, or other tests, must be evaluated on a case-by-case basis taking into account the criticality of the hardware element and the risk impact on achieving mission goals."
  - Before SC integration: "These requirements also apply to instruments and other spacecraft subsystem hardware prior to delivery for integration into the spacecraft. The Failure-free durations should be set dependent on the mission risk level, hardware complexity, and hardware criticality to the mission."
- GEVS 2.6.2.1 Applicability: For repaired equipment, usually a component (unit), subsequent testing shall be sufficient to demonstrate flight worthiness. If additional testing is expected at either the Subsystem or the Payload level, the number of cycles can be reduced so long as the total number of cycles satisfies the 12 cycle requirement.

Still No Definitive Methodology or Approach

GEVS - Mechanical Rework Requirements

- STRUCTURAL AND MECHANICAL VERIFICATION REQUIREMENTS
  - 2.4.2.8 Retest of Reworked Hardware – In many cases it is necessary to make modifications to hardware after a unit has been through a complete mechanical verification program. For example, replacing a capacitor on a circuit board in a electronics box that has already been through protoflight vibration testing. For this type of reworked hardware, the amount of additional mechanical testing required depends on the amount of rework done and the amount of disassembly performed as part of the rework. The primary objective of post-rework testing is to ensure proper workmanship has been achieved in performing the rework and in reassembling the component. As a minimum, the reworked component shall be subjected to a single axis workmanship random vibration test to the levels specified in Table 2.4-4. The determination of axis shall be made based on the direction necessary to provide the highest excitation of the reworked area. Testing may be required in more than one axis if a single axis test cannot be shown to adequately test all of the reworked area. If the amount of rework or disassembly required is significant, then 3-axis testing to acceptance levels may be necessary if they are higher than workmanship levels.

At Least Mechanical Has Something

Rework Cycling – How Many?

- The question "How many cycles do I need to test my reworked unit to?" comes up on every project.
  - Typically, thermal is asked to "approve/concur" with what the contractor has given the project…..or what the project has come up with (basis?)
  - Sometimes, this is said to be based on "institutional heritage/history" (what exactly is that history/heritage?). I'd think there would be an institutional process/requirement" for this?
- Usually, the only basis given is "we did this on xxx"…or "..we only replaced a couple resistors…"
- So, I decided to try to devise a means to quantify this for future use, initially for "low risk" missions, but then to modify for higher risk mission classifications.

Quantify Based on "Test Effectiveness"

Establish a Baseline

- To be able to quantify this, there has to be some basis for the "nominal" test approach at GSFC. My research and experience shows that this is GEVS (and GOLD Rules).
  - GEVS is written for "low risk" missions, and in the current vernacular, that means Class B Risk posture.
- Aerospace Corp has published many papers on how effective test programs are on "precipitating workmanship deficiencies", which is another way of saying "getting a latent defect in the unit to fail or exhibit anomalous performance". MIL-STD-344 uses "precipitation efficiency" (PE), expressed as a function of stress duration:

3 parameters are used to calculate how "effective" a thermal test is:

- **Quantity of cycles: GSFC metric is 12 before flight**
- **Overall temperature range: typ -10C to +50C for GSFC**
- **Transition rate: 20C/hour (typ for GSFC)**

PRECIPITATION EFFICIENCY - Precipitation efficiency is expressed as a function of stress duration in MIL-HDBK-344. It is given by

$$PE = 1 - e^{-kt} \quad (3)$$

where t is the number of the cycles and k is a stress constant that, for thermal cycling, is determined from

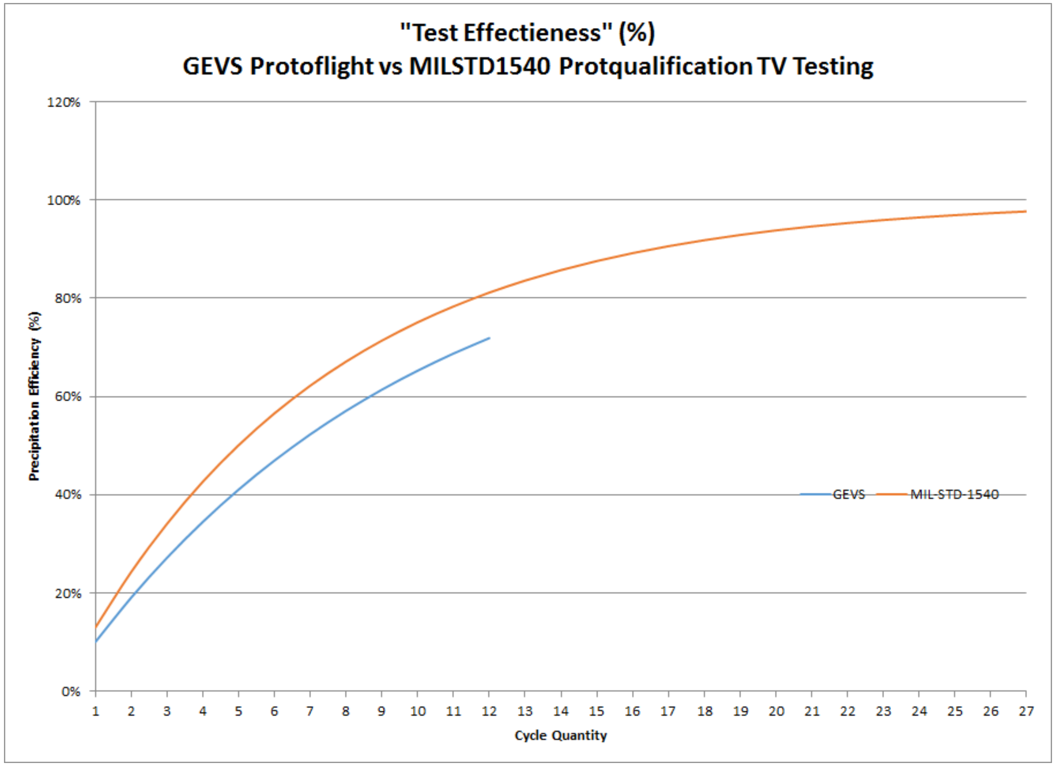
$$k = 0.0017(\Delta T + 0.6)^{0.6}[\ln(R + e)]^{3} \quad (4)$$

In Eq. (4), ΔT is the temperature range (in °C) and R is the temperature transition rate (in °C/min).

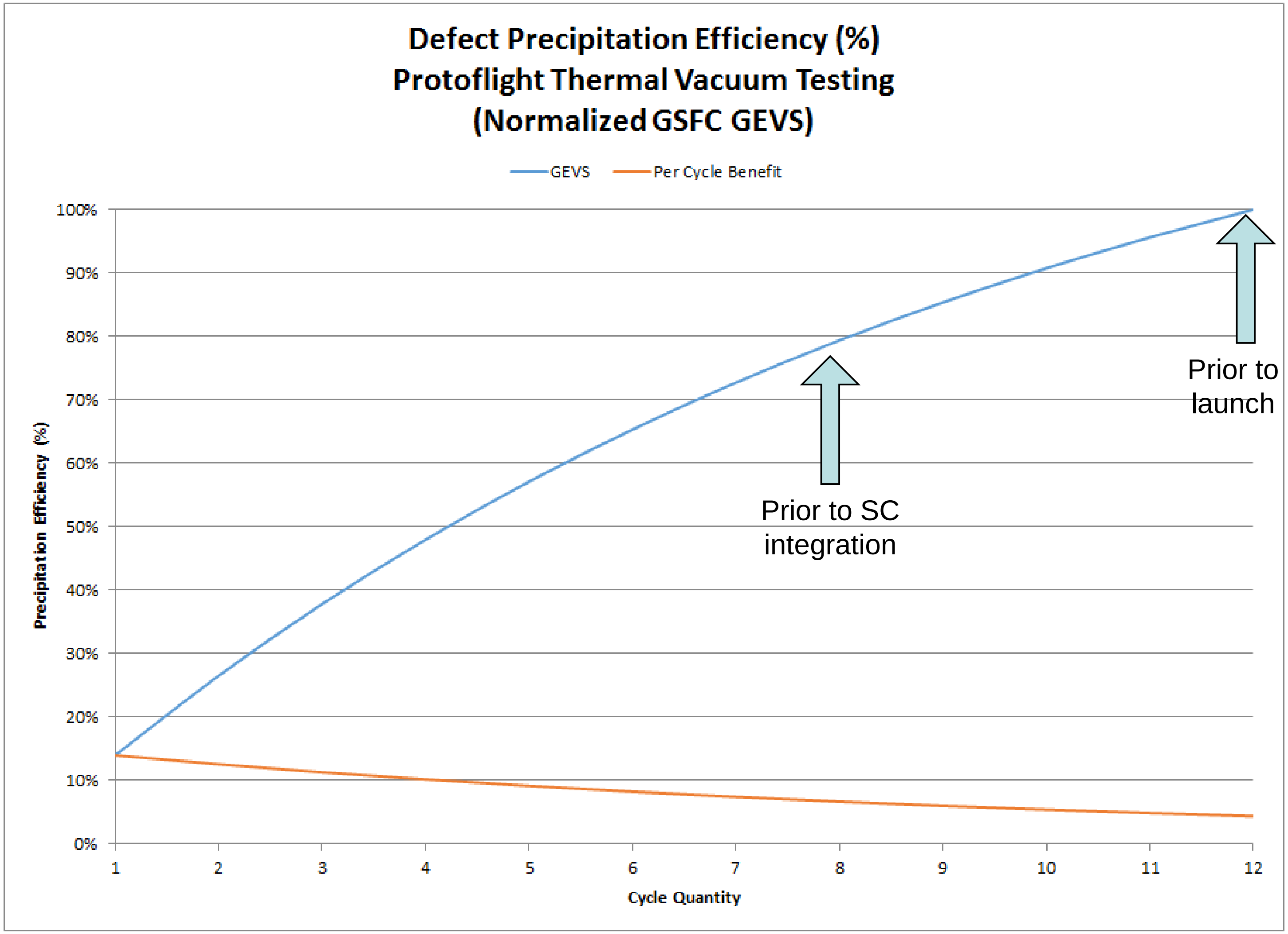
"Precipitation Efficiency" Equates to "Test Effectiveness"

TE: GEVS vs MIL-STD-1540

- GEVS
  - Unit: 8 TV (proto)
  - Transition rate: typ 20C/hr
  - Trange: -10C < Tproto < 50C
  - SC cycles “count” for ESS
- MIL-STD-1540
  - Unit: 23 TC + 4 TV (proto) (18 Tvac equiv?)
  - Transition rate: typ 30C/hr
  - Trange: -29C < Tproto < 66C
  - SC level doesn’t “count” for ESS, but only for system performance beyond predicts
- GEVS is our metric, so use it for basis of rework calculations.
  - Normalize to use for “regression test” TE calculations



Normalized GEVS Test Effectiveness



This can be applied to units, or boards, etc

Calculating Rework Cycles

- Now we have a basis for determining the test effectiveness of any unit based on it's planned thermal test program, that follows GEVS, or MIL-STD-1540, or JPL, etc…..
- When a unit is reworked, the of level of "test effectiveness" for those reworked parts resets to "zero", while those parts that are not reworked remain at the level of TE that was achieved before the rework. All parts then increase in TE during regression thermal cycles.
  - Define RTE: "Rework TE" starts at zero for reworked portion
  - Define TE(avg): "unit average" TE
    - Parts not reworked remain at the TE achieved prior to the rework
    - Parts reworked reset to 0% TE
- Use some level of "averaging" to calculate unit test effectiveness after rework. The question is to what level do we average ?
- I see 3 ways to do this:
  - Parts level – requires a parts list breakdown and knowledge of the circuit and part criticality & reliability, and failure modes/impact
  - Board/subassembly: a board that is reworked to any degree resets to "zero"
  - Unit: any rework to any degree resets the entire unit to "zero"

Rework Test Effectiveness (RTE)

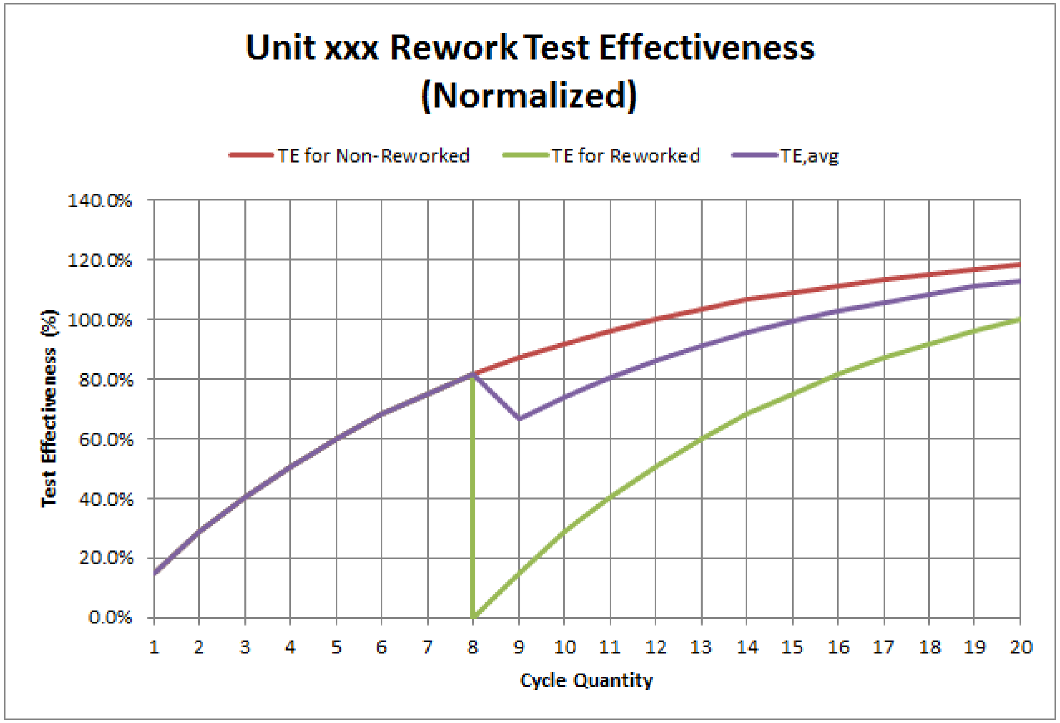
- I choose to use the board level, because it is impossible for me to burrow down to the part level for every board/unit (perhaps the Parts/Electrical Engineers can), but I can determine how many boards there are in a unit and how many are being reworked.
  - This is simplistic in that it makes no discrimination between replacing a single transistor or the entire board, or anything in between (see part level option)
- Further, with no guidance, I choose to use a “risk based” TE_{AVG} and RTE of:

Risk Class	TE,avg	RTE
– Class B:	100%	75%
– Class C:	90%	60%
– Class D:	80%	50%
– 7120.8/DNH:	70%	50%

- To summarize, this approach
  - determines the percentage of boards being reworked (TE reset to zero),
  - calculate how many cycles to
    - return the TEavg to 100% of where it was before the failure/rework <u>*AND*</u>
    - RTE (for the reworked portion(s) to the value shown above, for the point in the program that it was reworked..

Generic Example

- Unit xxx was reworked after 8 successful cycles
- Of the 7 boards in the box, 2 were reworked.



t(#)	Nominal Test Effectiveness	GEVS Normalized	TE for Non-Reworked	TE for Reworked	TE,avg
1	11.8%	15.16%	15.2%	15.2%	15.2%
2	22.2%	28.5%	28.5%	28.5%	28.5%
3	31.4%	40.3%	40.3%	40.3%	40.3%
4	39.5%	50.7%	50.7%	50.7%	50.7%
5	46.6%	59.9%	59.9%	59.9%	59.9%
6	52.9%	68.0%	68.0%	68.0%	68.0%
7	58.5%	75.1%	75.1%	75.1%	75.1%
8	63.4%	81.4%	81.4%	81.4%	81.4%
9	67.7%	87.0%	87.0%	15.2%	66.5%
10	71.5%	91.9%	91.9%	28.5%	73.8%
11	74.9%	96.2%	96.2%	40.3%	80.2%
12	77.8%	100.0%	100.0%	50.7%	85.9%
13	80.4%	103.4%	103.4%	59.9%	90.9%
14	82.7%	106.3%	106.3%	68.0%	95.4%
15	84.8%	108.9%	108.9%	75.1%	99.3%
16	86.6%	111.2%	111.2%	81.4%	102.7%
17	88.2%	113.3%	113.3%	87.0%	105.8%
18	89.6%	115.1%	115.1%	91.9%	108.4%
19	90.8%	116.7%	116.7%	96.2%	110.8%
20	91.9%	118.1%	118.1%	100.0%	112.9%

Risk Class	TE,avg	RTE
–Class B:	100%	75%
–Class C:	90%	60%
–Class D:	80%	50%
–7120.8/DNH:	70%	50%

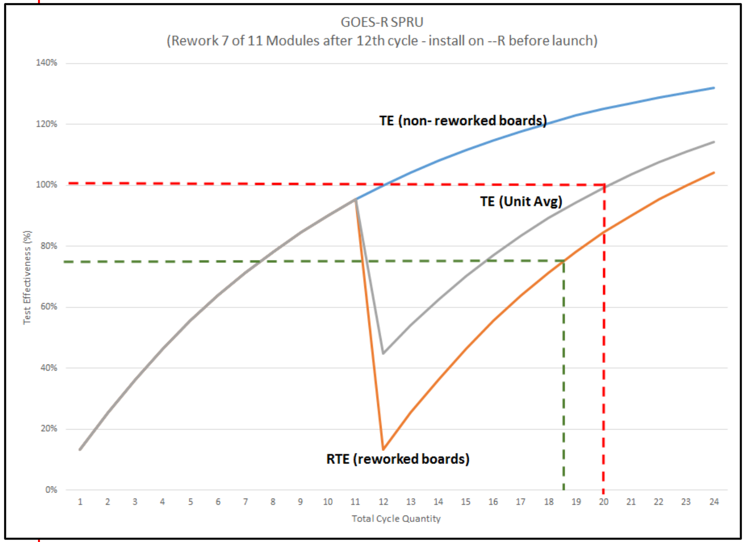
Example – GOESR RIUs and SIU

- GOES-R RIU1234 and SIU completed 8+4=12 cycles before rework. After regression testing, they will be installed on GOES-S prior to SCTV, so the goals for regression testing AND SCTV should be a unit average TE=83% and a RTE=75% for the reworked portions before re-installation on SC before SCTV.
  - The rework percentage varies between these units; presuming 2 boards in each had transistors replaced of the
    - 10 boards in RIU G1,G2,G3; 3 rework cycles ➔ RTE = 77% and unit avg TE = 107% (after 4 SCTV)
    - 8 boards in RIU G4; 3 rework cycles ➔ RTE = 70% and unit avg TE = 105% (after 4 SCTV)
    - 5 boards in SIU 3 rework cycles ➔ RTE = 70% and unit avg TE = 99% (after 4 SCTV)

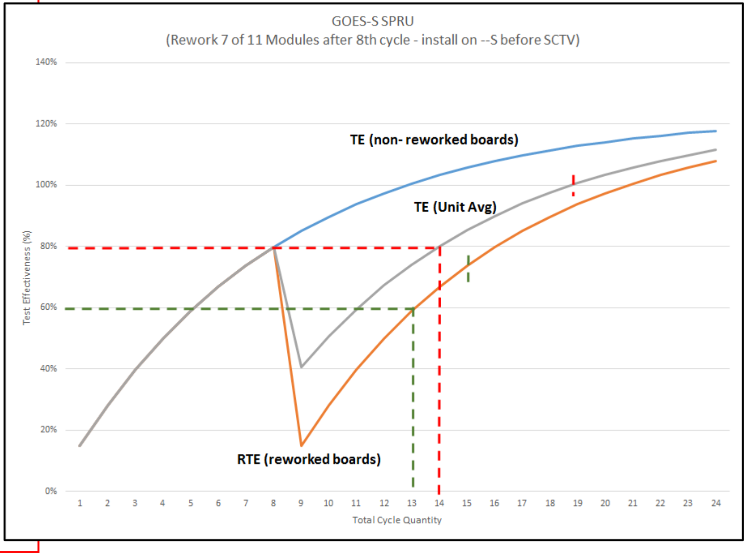
- Same rework for GOES-S RIU 1,2,3,4 and SIU, except they had only finished unit level testing, with no SC level thermal, but they were being installed on GOES-R for flight, so the regression test goals are a unit average TE=100% and a RTE=75% for the reworked portions before re-installation on GOES-R before launch (no further testing!)
  - TE was at 79.4%, but ideally needs to be 100% to be "ready" for flight
    - 10 boards in RIU G1,G2,G3; 7 rework cycles ➔ rework TE = 7% and unit avg TE = 102%
    - 8 boards in RIU G4; 4 rework cycles ➔ rework TE = 77% and unit avg TE = 100%
    - 5 boards in SIU 7 rework cycles ➔ rework TE = 77% and unit avg TE = 95%

Example – GOESR SPRU

- GOES-R SPRU reworked after 12 cycles (11 successful cycles really…..).
  - To be reinstalled on –R SC prior to launch, so RTE to "pre-launch levels", which for Class B is
    - 75% of 12 cycle RTE = 75% (8 rework cycles)
    - TE,avg = 100% (9 rework cycles) ←
  - Project did 3 cycles that result in:
    - RTE: 36%
    - TE,avg: 62%

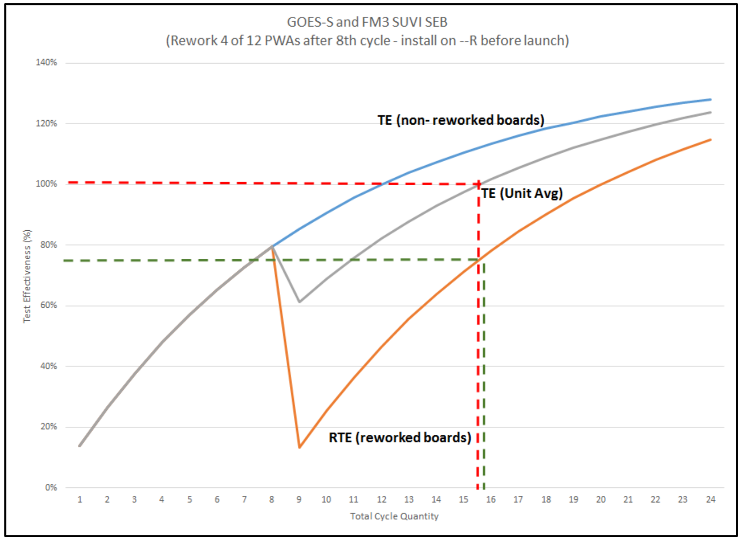


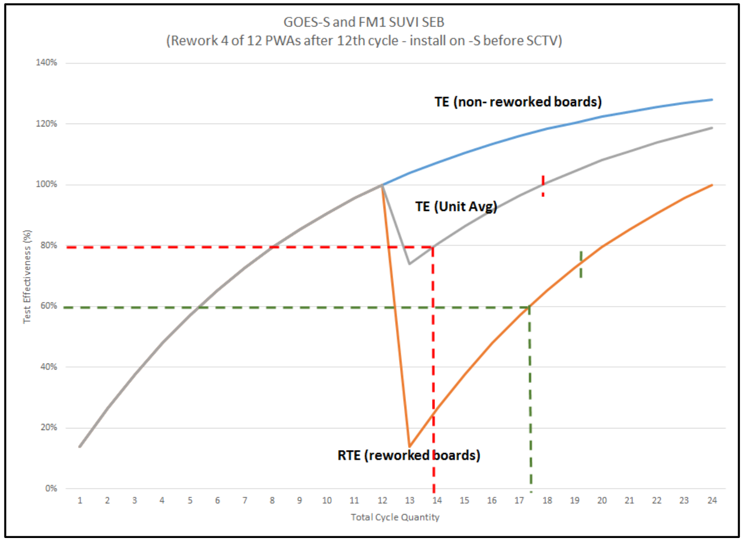
- GOES-S SPRU reworked after 8 cycles.
  - To be reinstalled on –S SC prior to SCTV, so RTE to "pre-SCTV levels", which for Class B is
    - 75% of 8 cycle RTE = 59% (5 rework cycles)
    - TE,avg = 80% at 8 cycles (6 rework cycles) ←
  - Project did 3 cycles (launch) that result in:
    - RTE: 40% (74%)
    - TE,avg: 59% (85%)



Example – GOESR SUVI SEB

- FM3 SEB reworked after 8 ITV cycles; 4 of 12 PWAs reworked.
  - To be installed on –R SC before launch, so RTE to “pre-launch levels”, which for Class B is:
    - 75% of 12 cycle RTE = 75% (4 rework cycles)
    - TE,avg = 100% (4 rework cycles) ←
  - Project did 3 cycles that result in:
    - RTE: 71%
    - TE,avg: 97%
- FM1 SEB reworked after –R SCTV (12 cycles); 4 of 12 PWAs reworked
  - To be installed on –S SC before SCTV, so RTE to “pre-SCTV levels”, which for Class B is:
    - 75% of 8 cycle TE; RTE = 60% (2 rework cycles)
    - 79.4% T,avg (5 rework cycles) ←
  - Project did 3 cycles (launch) that result in:
    - RTE: 38% (73%)
    - TE,avg: 86% (105%)





Rework Testing: Summary

- This approach provides a basis for determining the number of rework thermal vacuum cycles to return the reworked unit to a level of test effectiveness commensurate with the project's risk classification.

- It addresses electronics boxes primarily since that is the usual item that gets reworked.

- Every project will have many permutations that would need to be considered uniquely…

Collaboration Between Mission Assurance (Risk, Parts) and Electrical/Thermal To Prepare a Plan or for Specific Units

Lessons Learned

LL #

1) Have extra sink measurement devices (ESD, AC, etc) and TC channels available to install when you notice “undocumented” MGSE blocking FOV to cold wall or target…..if it can’t be moved/improved, you need to know the sink.
2) Seriously consider using “back reflectors” on watrods. The spacing and setback can be adjusted to still give ~5% blockage, yet minimizes the “errant energy” scattering thru the chamber….and reduces how many power plants are needed to run the test.
3) Trust but verify – if no engineering test data available for a critical device or instrumentation: REPEAT IT !
4) Always check for property adjustment, and re-measure if needed, when IR sources are used at temperatures greater than “near ambient”…do the math to see what percentage of energy for your test is in the typically un-measured spectral range, and run a parametric to see how sensitive your temperature predictions are if ε is wrong.
    1) [Note: the same thing needs to be done for a solar sim test using the as-measured spectral distribution of the beam, and adjust α’s as needed]
5) Project should REQUIRE correlated thermal models for ALL thrusters/engines.
6) Never rely on taped TCs on hardware that gets hot and/or is expected to cover a large temperature range.
7) Pay attention to EGSE and MGSE – thermal issues on this stuff can also STOP or DELAY your test success !!
8) Always update dissipations in thermal model BEFORE the post-SCTV correlation…..I don’t care how busy you are pre-test. It C-A-N have hardware impact !!

GOES-R,-S Path Forward

- Pre-Ship Review held July 12-13, 2016
  - Ship to Kennedy Space Center (AstroTech) Aug 22nd.
  - Launch Readiness Date: Nov 4th, 2016
  - Mission rehearsals ongoing; #4 is next week

- Issues for Launch:
  - Liquid Apogee Engine (LAE): same engine on another project experienced "burn-through" during orbit raising phase, on the 4th burn of this engine.

- GOES-S: SCTV planned for "Spring 2017".

Conclusion/Summary

- SCTV is a very complex and longest duration environmental test.
- Typical thermal balance duration (GOES-R was only 7 days) does not justify cutting for schedule purposes….even for “identical” follow on spacecraft. It is the only verification for thermal subsystem performance.
- Watrods provide better hot-cold simulation than heater plates,
  - Using watrods for environmental simulation requires significant effort to mitigate potential issues.
  - Thermal involvement into MGSE design is not recommended.
- Never reduce SCTV cycle quantity, especially on LOW risk missions !!!